P. L. Grossman
The Cooper Union
for the Advancement
of Science and Art
41 Cooper Square
New York, N.Y. 10003

"Mechanical Evaluation of Non-Rigid Canes"

American Foundation For The Blind


EX-
LIBRIS

MECHANICAL EVALUATION OF NON-RIGID CANES

Submitted to: Alex Townsend, Director, Sensory Aids Development
The American Foundation for the Blind
15 West 16th Street
New York, New York 10011

Submitted by: The Cooper Union Research Foundation
The Cooper Union School of Engineering
Cooper Square,
New York, New York 10003

Project Director - Perry L. Grossman
Student Investigator - Robert F. Judd

Date: August 1977

ABSTRACT

In order to provide guidance to individuals and agencies purchasing non-rigid canes, a mechanical evaluation of ten collapsible canes commonly used by the visually impaired was performed to determine their comparative effectiveness and ability to withstand various situations encountered. Each cane was examined, tested and rated with respect to overall characteristics, tubing, joints, tip, handle, inner elements, safety, durability and serviceability.

This report is divided into three parts: cane identification and ratings; experimental programs and results; conclusions and summary. We believe the information herein to be valuable to the consumer for assistance in the appropriate selection of a cane and to the manufacturer in order to improve existing cane design.

Summary

Highly Recommended - Canes 3, 10 and 5.

Recommended - Canes 6,7,8 and 9.

Not Recommended - Canes 1,2 and 4.

Table of Contents

PART 1: THE CANES

A. Cane Identification

B. Cane Ratings

A. Cane Identification

Cane 1 - Autofold Cane, Hycor Inc.

Cane 2 - Cable Cane, Hycor Inc.

Cane 3 - Collapsible Aluminum Cane,
California Industries for the Blind.

Cane 4 - Men's Pocket Cane, AFB.

Cane 5 - Mahler Heavy Duty,
Aluminum Folding Cane, AFB.

Cane 6 - Mahler Standard,
Aluminum Folding Cane, AFB.

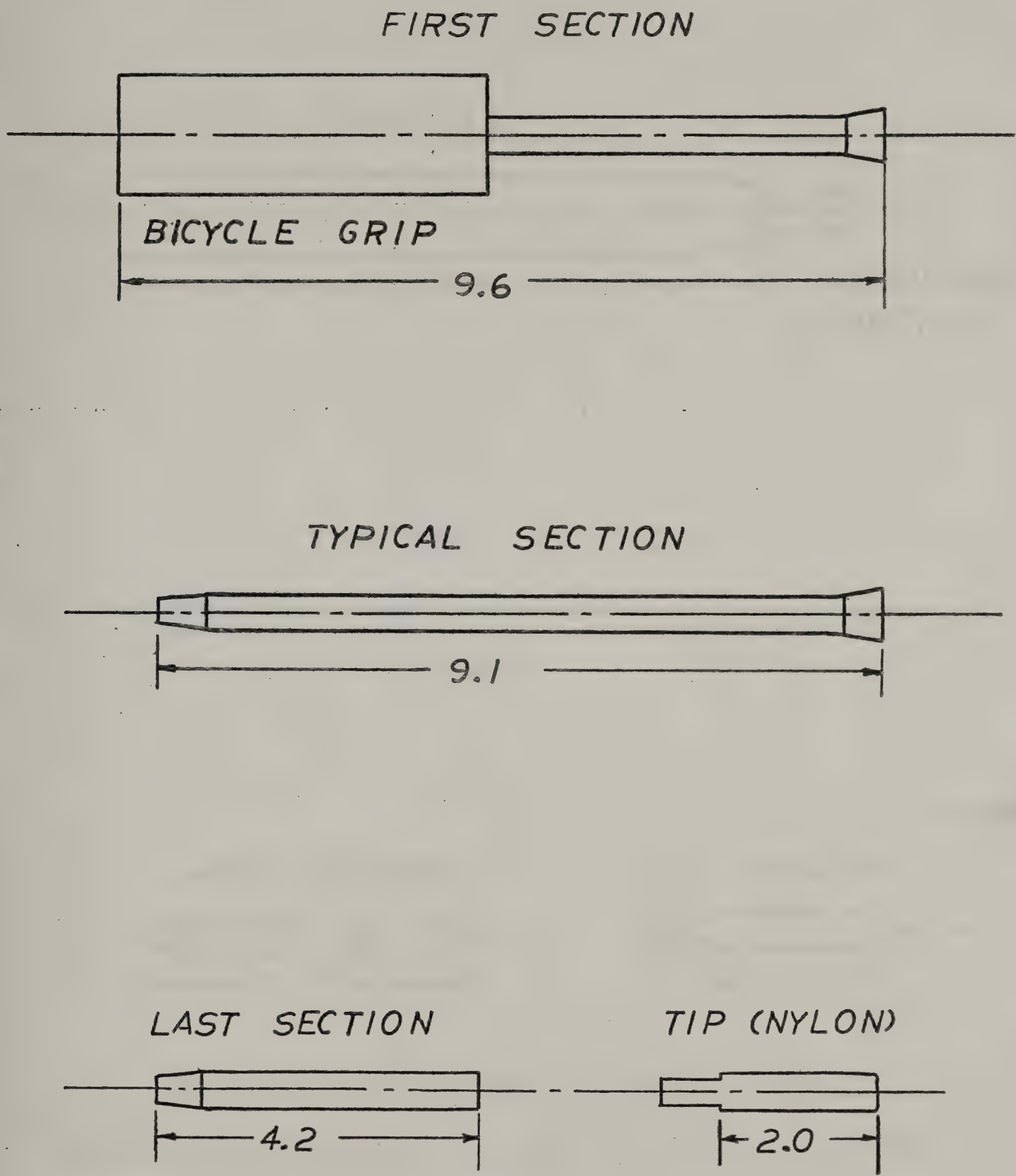
Cane 7 - Mahler Telescopic Cane with Crook Handle,
AFB.

Cane 8 - Mahler Telescopic Cane with Plastic Handle,
AFB.

Cane 9 - Rigid-Fold Cane, Rigid Fold.

Cane 10 - Telescoping Fiberglass Cane,
W.L. Crandell.

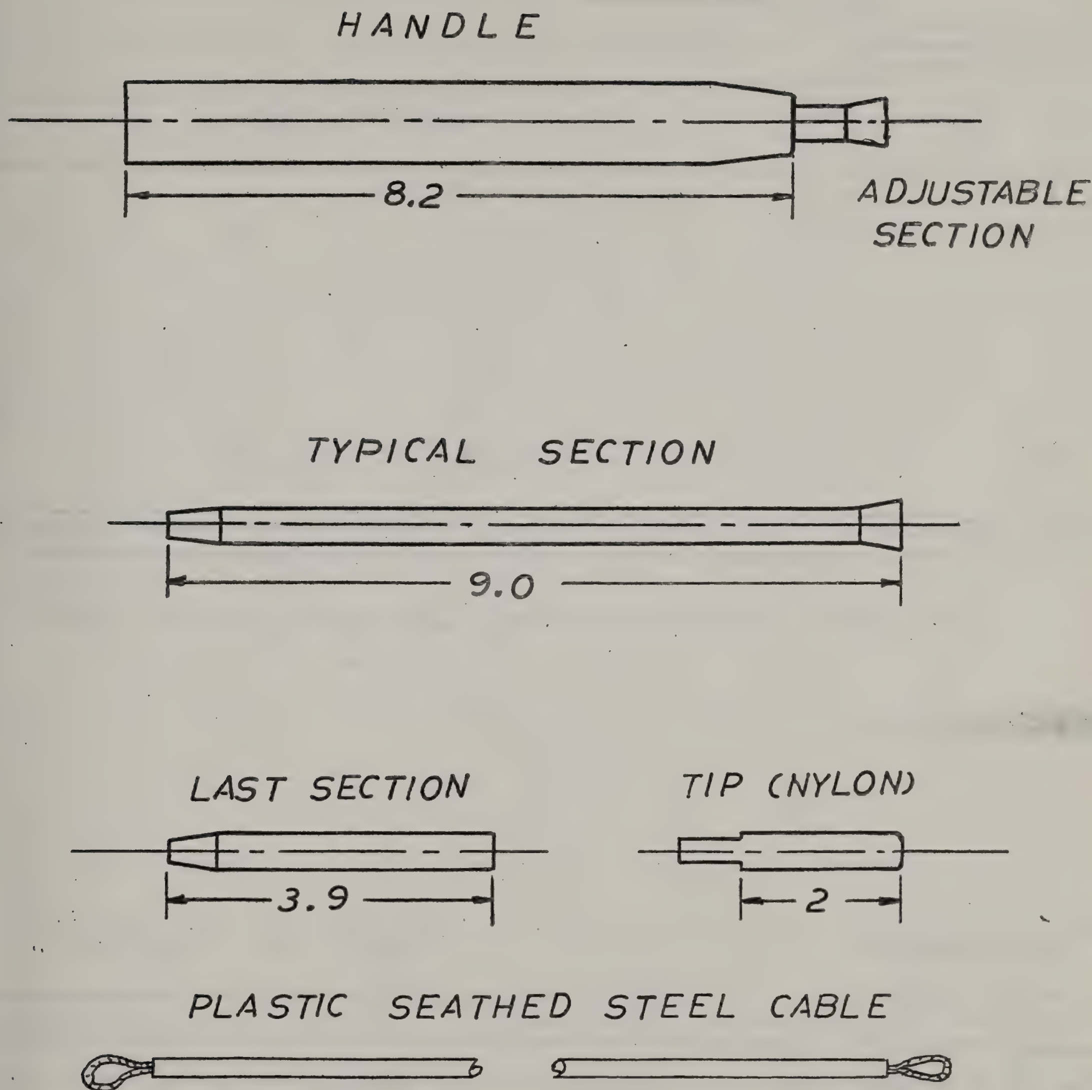
FIG 1-A CANE 1



ALL TUBING 1/2 DIA AND .050 THICK

TAPERS ARE 11° AND 1/2 LONG

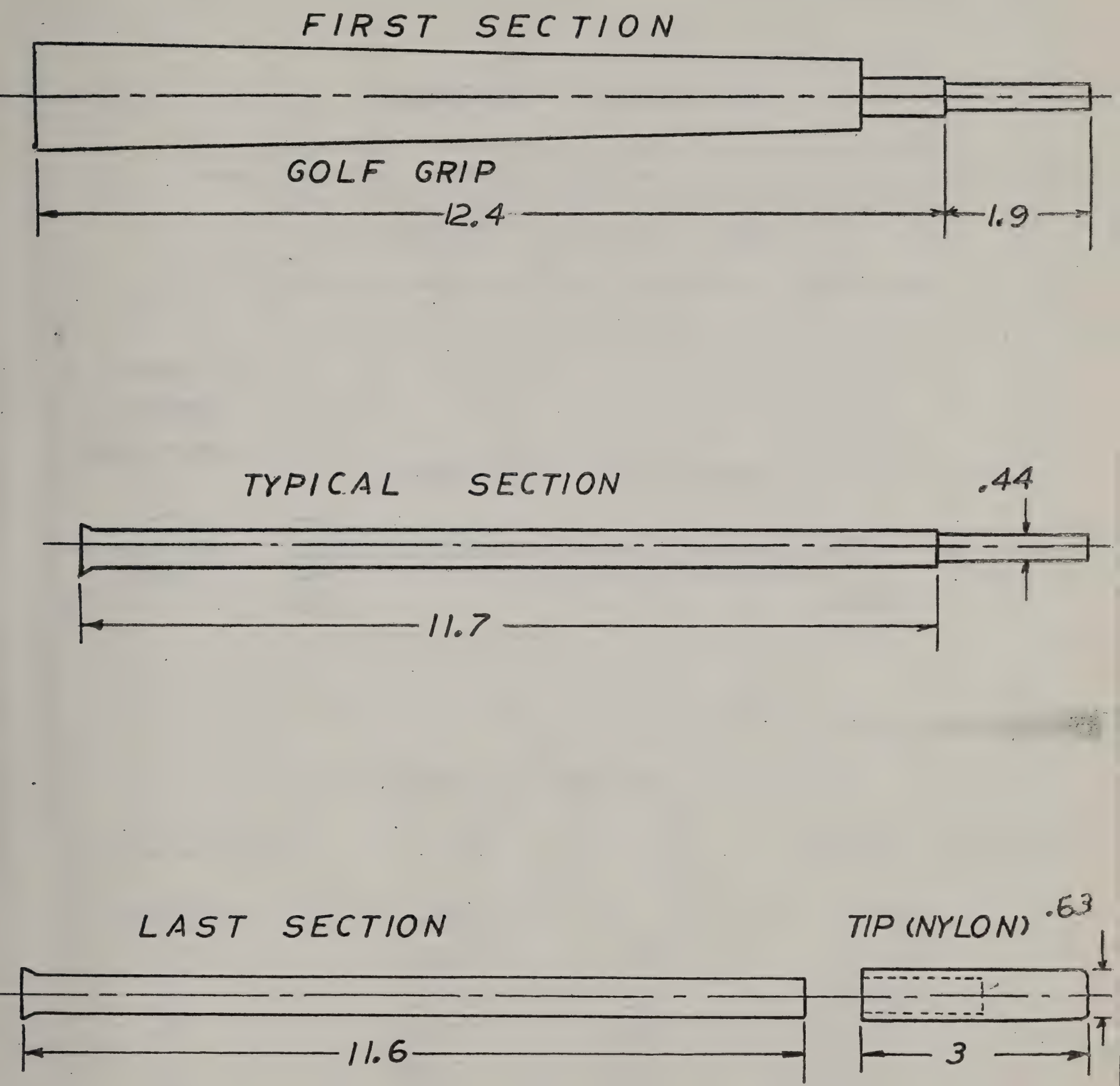
FIG 1B CANE 2



ALL TUBING 1/2 DIA AND .050 THICK

TAPERS ARE 11° AND 1/2 LONG

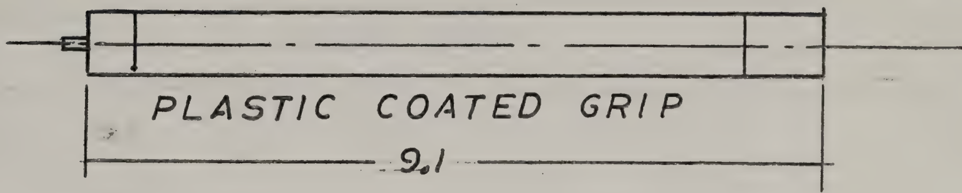
FIG 1-C CANE 3



ALL TUBING 1/2 DIA AND .035 THICK

FIG 1- D CANE 4

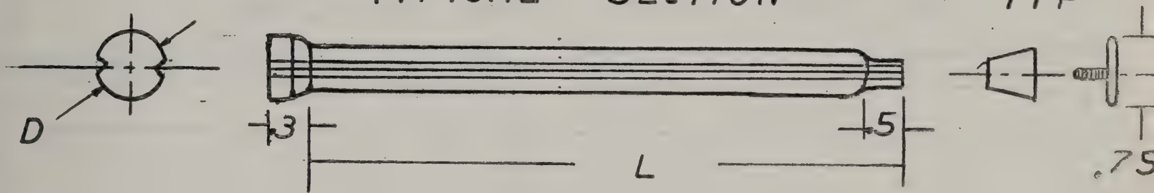
HANDLE SECTION



TYPICAL CROSS SECTION

TYPICAL SECTION

TIP

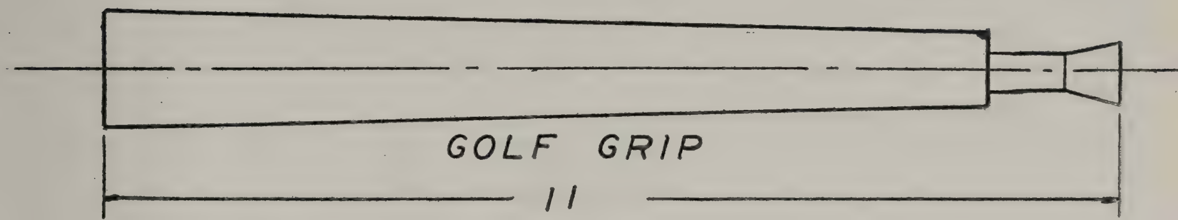


TUBING SPECS.

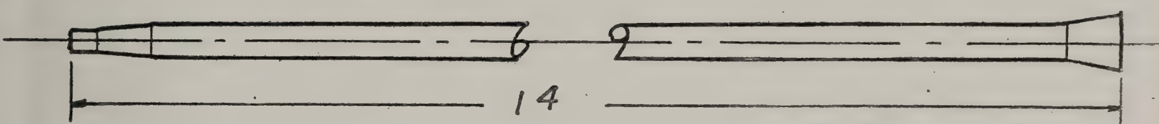
SECTION	D	L	WALL THICK.
HANDLE	.710		.015
2	.625	7.4	.015
3	.570	7.2	.015
4	.515	6.9	.015
5	.460	6.5	.015
6	.405	6.2	.015
7	.350	5.9	.015
8	.300	5.6	.015

FIG 1-E CANE 5

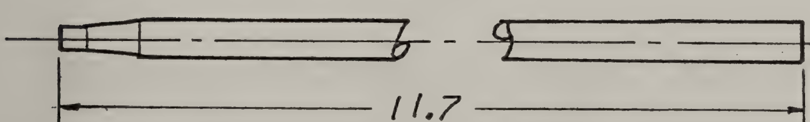
FIRST SECTION

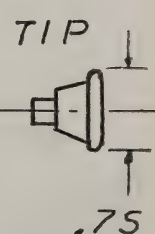


SECOND AND THIRD SECTION



LAST SECTION



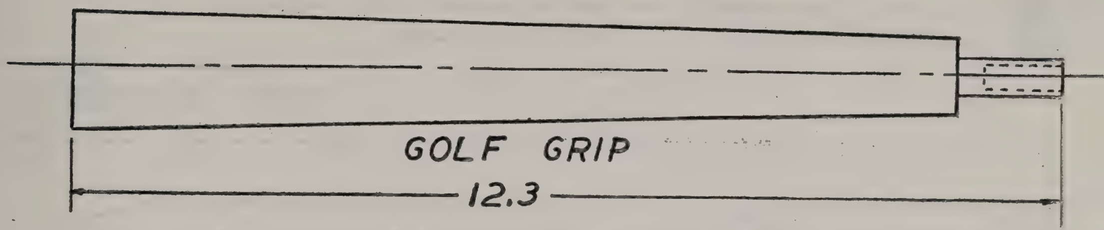


ALL TUBING 1/2 DIA AND .050 THICK

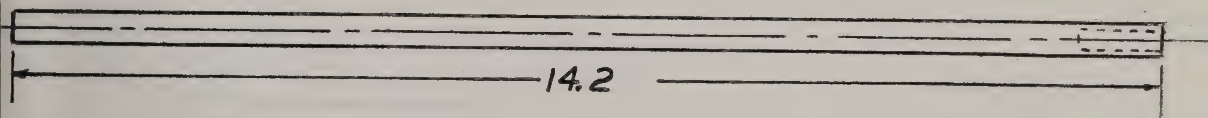
TAPERS ARE 9° AND .7 LONG

FIG 1-F CANE 6

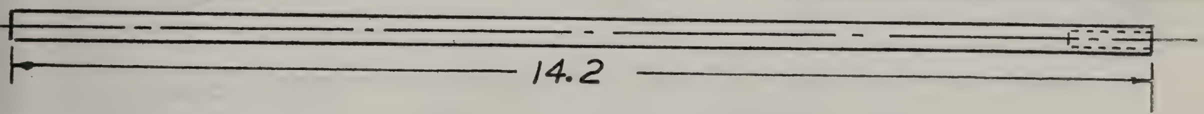
FIRST SECTION 1/2 TUBING



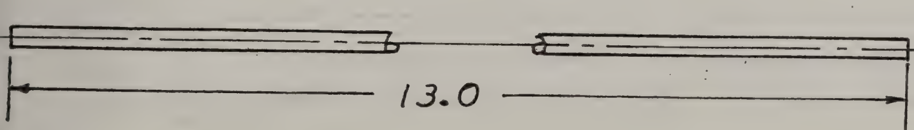
SECOND SECTION 7/16 TUBING



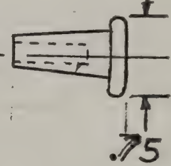
THIRD SECTION 3/8 TUBING



FOURTH SECTION 5/16 TUBING

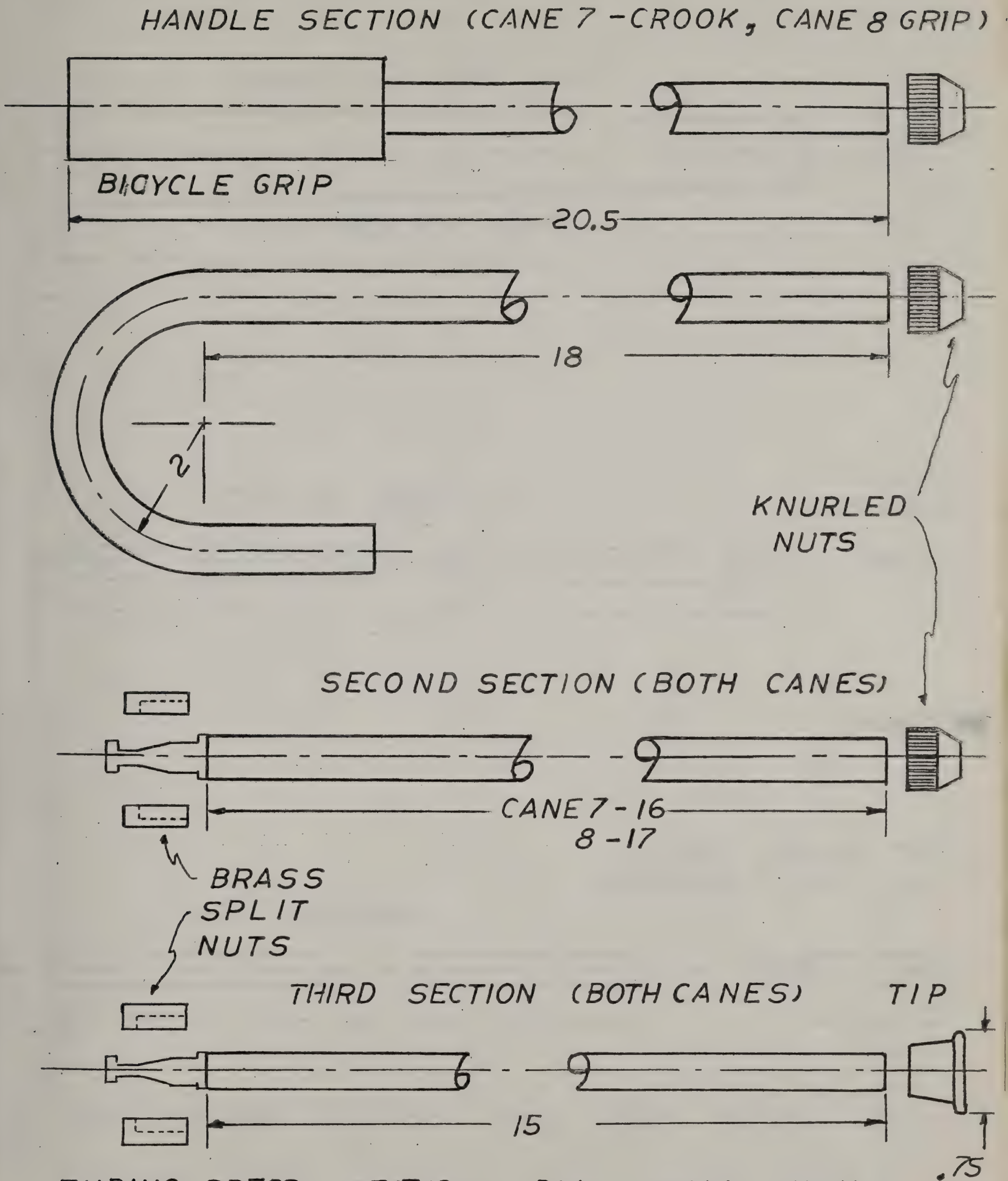


TIP



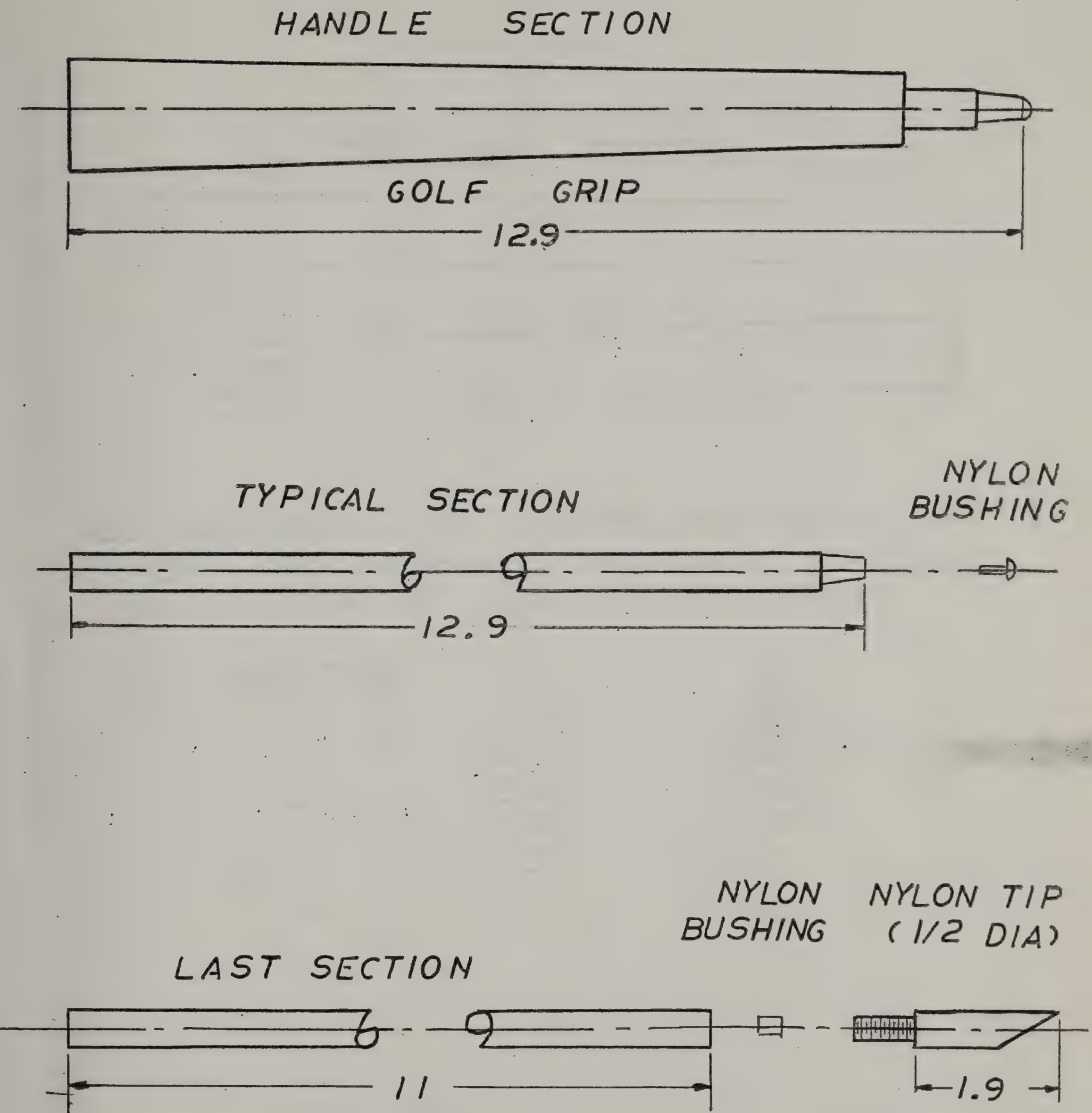
ALL TUBING .050 THICK

FIG 1-G CANES 7 AND 8



TUBING SPECS. SECTION	DIA.	WALL THICK.
HANDLE	.750	.050
SECOND	.625	.050
THIRD	.500	.050

FIG 1-H CANE 9

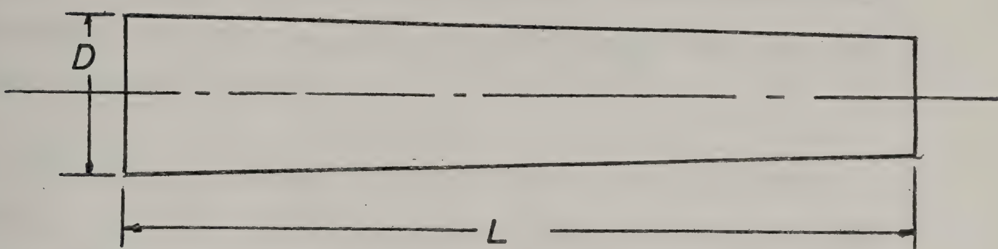


ALL TUBING 1/2 DIA AND .070 THICK

TAPERS ARE 5° AND .650 LONG

FIG 1-I CANE 10

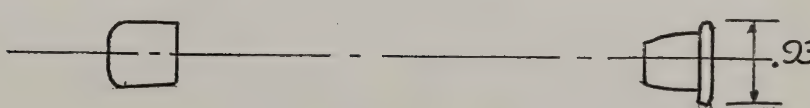
TYPICAL SECTION



ALL SECTIONS ARE FIBERGLASS WITH .3° TAPER AND NOMINAL THICKNESS OF .020. THE FOLLOWING DIMENSIONS APPLY:

SECTION	L	D
1	10.3	.685
2	10.0	.600
3	10.0	.505
4	9.5	.415
5	9.5	.315
6	9.0	.230

END CAP TIP



B. Cane Ratings

Table 1 gives a summary of how each cane rated in each of the major areas of investigation. The reasons for the ratings are fully explained in the appropriate section of the technical report.

After an evaluation of the ratings, the canes were divided into three categories and a short paragraph explaining the reason for each overall rating is included.

This portion of the report serves only as a summary and guide to the canes evaluated. It is not intended to be a detailed discussion about the features of each cane. A complete analysis of each characteristic is given in the appropriate technical section in Part 2 of this report.

Table 1 - Cane Ratings

Cane	1	2	3	4	5	6	7	8	9	10
Effort Required	G	F	G	G	G	G	P	P	F	E
Compactness	G	G	G	E	G	G	P	P	G	E
Resistance to Deformation	G	G	G	P	G	F	E	E	G	P
Transverse Stiffness	G	G	G	F	G	F	E	E	G	P
Coating Resistance	F	F	G	E	E	G	E	E	G	G
Joint Looseness	F	E	G	P	G	F	G	G	G	E
Joint Effectiveness	F	F	G	F	G	G	G	G	F	E
Ease of Opening	P	G	G	G	P	G	F	F	P	E
Handle Comfort	F	P	E	F	E	E	F	F	E	F
Tip	USER PREFERENCE									
Night Visibility	F	F	E	G	F	E	G	G	E	F
Accidental Collapse	E	E	E	P	E	E	E	E	E	P
Loose Tip	E	E	G	P	E	E	E	E	E	F
Durability	P	P	G	P	E	G	E	E	E	E
Serviceability	P	G	F	P	F	F	G	G	G	E

Notes: E - excellent

G - good

F - fair

P - poor

Highly Recommended

Cane 3: This cane rated well in all categories tested except for user serviceability.

Cane 10: This cane is highly recommended for someone who needs a compact and extremely light cane, but who is willing to sacrifice the rigidity and strength of the metal cane.

Cane 5: Although this cane is more difficult to open and close, it rated well in most categories. However, it is stronger and will last longer than Canes 3 and 10.

Recommended

Cane 6: This cane is the lightest of all the metal canes, however, for this the buyer must live with loose joints, durability problems, and, of course, the weakest metal cane. (Although, it is much stronger than Cane 10).

Canes 7 and 8: These canes rated well in most categories except for user effort and compactness, two very important areas. In addition, their handles were uncomfortable and they took a long time to open.

Cane 9: This cane has only two problems, but they are both very important. First, it is slightly heavier than most of the other canes. Also, the joints stick often and tight creating great difficulty on the user when folding it.

Not Recommended

Cane 1: This cane is uncomfortable to hold, hard to open, contains loose joints, has durability problems and is not user serviceable.

Cane 2: Because of its extremely uncomfortable handle and short expected life, this cane is not recommended.

Cane 4: This cane is not recommended because of loose joints, ease of deformation, short life, safety problems, and poor serviceability.

PART 2: EXPERIMENTAL PROGRAM AND RESULTS

A. Overall Characteristics.

B. Tubing.

C. Joints.

D. Tip.

E. Handle.

F. Inner Elements.

G. Safety.

I. Durability.

H. Serviceability.

A. Overall Characteristics

1. Introduction

The overall features of the canes are the first and most easily recognized properties, with the weight, length and fulcrume location (balance point) being the most important characteristics. These properties govern the amount of effort the user must impose at the handle to manipulate the cane. The weight is the equivalent force required to lift the cane while the product between force and moment arm (distance) yeilds the torque necessary to rotate the cane.

When a cane is freely supported (free tip) the user must not only resist the weight of the cane but also the moment of the weight force. This moment is equal to the product between the weight of the cane and the horizontal projection of the distance from the handle to the fulcrum. The tip-rotation-ratio is defined as the percentage of the maximum torque (weight times horizontal projection of the cane length) necessary to prevent rotation. The lower the tip-rotation-ratio the less effort required by the user when the cane is freely supported. Thus, the closer the fulcrum to the cane handle the lower the tip-rotation-ration and the less effort required to resist the moment.

In addition to the tip-rotation-ratio, another important cane parameter is the tip-weight-ratio, defined as the percentage of the weight which is supported by the tip while the cane is held in its normal operating position. Of course, the rest of the weight is then supported by the user of the cane. The higher the tip-weight-ratio the less effort required by the user when the cane is in contact with the ground. Thus, the closer the fulcrum is to the cane tip the greater the tip-weight-ratio and the less effort required by the user when operating the cane.

As the fulcrum point is moved from the handle toward the tip of the cane the tip-rotation-ratio and the tip-weight-ratio increase, therefore, user fatigue decreases for ground operation but increases for freely-suspended operation. The optimal condition for a given individual is obviously obtained as a compromise by adjusting the fulcrum so that the user is moderately comfortable for both modes of operation.

The tip-rotation-ratio and tip-weight-ratio are given by the identical formula (See Appendix A)

$$R = L'/L \qquad (1)$$

where L' = distance from handle to fulcrum.

and L = length of cane.

The final overall features of the non-rigid cane are the collapsed dimensions. Since the purpose of buying a cane of this kind is to be able to fold it up so that it can be hidden or conveniently held, it is considered important that the smallest overall dimensions accommodate compactness.

2. Procedure

The canes were first weighed and measured. Then they were balanced to determine the position of the fulcrum point. Next, the ratios L'/L (handle to fulcrum distance/length) was computed. Finally, the collapsed dimensions were taken. These consist of the maximum collapsed length and the circumference around the widest part of the folded cane.

3. Results

Table 2 summarizes the results of the measurements and caluclations for the overall cane characteristics.

4. Discussion

a. Cane Weight

Canes 1 through 9 vary in weight from approximately ½ to 3/4 of a pound with canes 7 and 8 being somewhat heavier than the rest. In comparison, Cane 10 is extremely lighter than the rest with its weight ratio varying from approximately .2 to .3 in comparison to the others.

Table 2: Overall Cane Characteristics

Cane	Overall Weight (lbs)	Overall Length (inches)	R = L'/L	Collapsed Length (inches)	Circumference (inches)
1	.52	50.5	.42	10.0	5.5
2	.67	48.5	.36	9.5	5.8
3	.53	49.2	.39	14.4	4.8
4	.55	51.0 [1]	.44	9.8	2.4
5	.57	50.0	.43	14.3	4.8
6	.48	52.2	.39	14.5	4.5
7	.77	53.8 [2]	.45 [2]	22.5	2.3 [3] 10.6
8	.78	52.0 [2]	.45 [2]	23.0	3.2
9	.64	50.0 [4]	.41	13.4	4.5
10	.16	50.9	.49	11.5	3.0

Notes:

1 - the length of the eyelet to hold the wrist strap is not included.

2 - cane fully extended.

3 - for largest tubing and crooked handle, respectively.

4 - length of the plastic lock not included.

b. Fulcrum Position

The ratio of L'/L varies from a low of .39 to a high of .49 for the ten canes tested. Canes with a lower ratio are easier to handle off the ground while those with a higher ratio handle better in contact with the ground. The results here indicate that the canes rate about the same in this category with no outstanding differences among them. Combining these results with the appropriate results in the field survey may indicate what compromise in fulcrum position is most generally (but not individually) best. It is the feeling here that a ratio of .4 to .5 is appropriate for the design of such canes and variations within this range would not significantly alter the sensitivity of the user to force and torque.

c. Compactness

Canes 4 and 10 are the top rated with respect to collapse size with cane 4 being best. Next, canes 1,2,3,5,6 and 9 rate about equally and moderately well in comparison in this category. Canes 7 and 8 both receive poor ratings because their minimum lengths are about twice as long (2 feet approximately) as the other canes producing a somewhat bulky cane in the most condensed state.

We can conclude here than an appropriate collapse length should be somewhere from 9 to 15 inches while the range for the minimum circumferences should be between 2.5 and 6 inches.

B. Tubing

1. Introduction

One common mode of failure of the canes is that when they are subjected to abnormal environments there will be permanent deformation. The ease at which the canes deform is of major concern in this section. Also covered is the transverse (beam) flexibility of the canes along with a discussion on how long this covering or coating on the tubing will maintain its appearance.

The cane resistance to permanent deformation is a function of the physical properties of the material, the cane geometry, the method of support, and the type of loads applied. It means nothing to say that a given load will deform a cane. If we should place the load elsewhere, reorient the load, or change the method of support, different results will occur. Since the canes will deform only under unusual circumstances, it is impossible to predict all the loading situations. However, it is possible to determine the relative resistance to deformation. The relative resistance to deformation is dependent only on the physical and geometrical properties of the cane.

It is the section modulus (geometrical) that resists the applied transverse loads. For bending (beam) deformation the geometrical parameter is the second area moment of inertia which for a hollow circular section is given by

$$I = \frac{\pi}{64}\left(D_o^4 - D_i^4\right) \qquad (2)$$

where D_o = the outside diameter of the tube

and D_i = the inside diameter of the tube.

The physical properties of the material will determine the maximum stresses and the relaltion between stress (physical) and strain(geometrical). Of primary importance are the following properties:

Ultimate Strength - the maximum normal stress a material can sustain before breakage occurs.

Yield Stress - the maximum normal stress a material can sustain before permanent deformation occurs.

Young's Modulus - the ratio of normal stress to corresponding normal strain.

Shearing Strength - the maximum shearing stress a material can sustain before breakage occurs.

If we assume that joints have no effect (They in reality may have a significant effect, however, this section is concerned with the tubing performance. The affect that the joints have on cane performance is discussed in the next section.), classical beam theory can be applied to find a means of finding the ease of transerve deformation. For a beam

$$M = \sigma Z \qquad (3)$$

where M = the bending moment (computed directly from the loading)

σ = the outer fiber (maximum) bending stress

and Z = the section modulus ($Z = I/D_o/2$) (4)

If we use the yield stress for the material, Equation (3) may be utlized to calculate the bending moment required to cause permanent deformation. Since the bending moment is directly proportional to the load, this is a good method of finding the ease of transverse deformation for any lateral loading pattern.

We define arbitrarily the bending moment for Cane 1 as a standard. By dividing the critical bending moment of the other canes by this value, we have a rating system which measures the relative resistance to permanent deformation. For canes of varying cross sections, two ratings will be given. The higher rating will be for the largest section while the lower value corresponds to the smallest section (see Appendix B). It can be shown that no matter what loads are involved the actual ease of permanent deformation will lie somehwere between these two values. In most of the common loading situations the actual value will be closer to the lower number (see Appendix C).

In addition to deformation caused by transverse loading, there could be transverse deformation caused by axial compressive loading. Again, the axial load which would cause transverse deformation (critical buckling force) is a function of how the cane is supported. However, for the cane application it is

practical to assume a column with pinned ends (simply supported beam). A doubly pinned column is defined as a thin member under axial compression whose ends cannot move in the transverse direction but can freely rotate. This is schematically represented by Figure 2 .

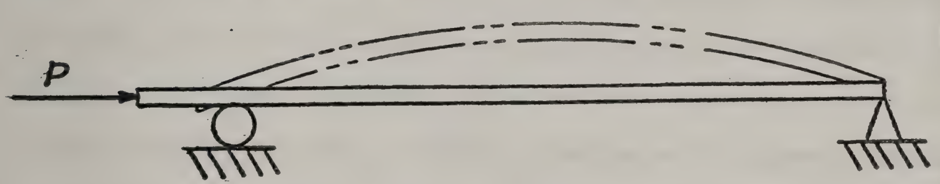


Figure 2 - Simply Supported Column

This picture is representative of a cane tip running into an obstruction (curb or wall) and user push causing the compressive load.

Unlike the transverse loading situation, the joints will have very little effect when the cane is compressively loaded. The affects which cannot be neglected are an initial curve in the cane, loads which are applied slightly eccentric with the cane axis, and defects in the material. Even though the last two situations will probably be not of much concern here, the

first one is very important. Loose joints and alignment are quite common primary affects here. Since all this produces extreme complications in the theoretical formulation only experimental results will be presented.

The more rigid the cane the more information obtained by the user. As with the resistance to permanent deformation and the elastic stability (critical buckling load) of the cane, the flexural spring stiffness is a function of the supports and the load application. However, if practical considerations are given to the cane situation, a simple loading and support diagram can be deduced. In normal use the cane is gently tapped on the ground, or an equivalent approach is that the cane is stationary and the ground is coming up and tapping on the cane. If this view is taken then it is readily seen that this is equivalent to the classic flexure problem in solid mechanics, ie. a cantelever beam subjected to a concentrated transverse force at the free end as shown in Figure 3 .

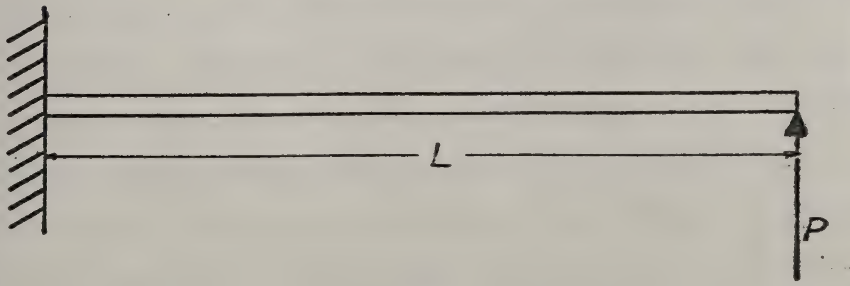


Figure 3 - Flexure Problem

One end is firmly fixed (by the users hand) and the load is applied to the other end (the tip hitting the ground). Once the loading situation and method of support are determined, the calculation of the equivalent spring constant (stiffness coefficient) is routine. This is provided in Appendix D.

Lastly, we consider the ease that the coating or covering of the tubing has to chipping or scratching. There are three basic ways the tubing is finished: paint; tape or adhesive backed coating; finished metal (polishing, anodizing or plating).

The painted surfaces are the most prone to chipping and scratching, both of which will be quite visible because the aluminum will show through.

Since the adhesive coatings are not as hard or brittle as paint, chipping is impossible. However, being softer it is more prone to scratching than paint. Even though it scratches more easily the scratches do not expose the aluminum. Thus, they are less noticeable than the scratches on the painted surfaces.

The best way to prevent marring a surface is to finish the metal itself. Obviously, chipping is impossible and the scratches can only be noticed upon close examination. In addition to the scratches being almost undetectable, it is very difficult to scratch at all because it is metal. Scratching is almost impossible if the tube is plated with an extremely hard surface such as nickel-chromium.

2. Procedure

The canes were disassembled and all appropriate measurements taken to determine the geometrical properties of the tubings. The manufacturers of the canes were contacted so that the alloy used and its temper could be accurately determined.

Next, the resistance to permanent deformation and the stiffness coefficients were computed. The canes were placed on a compressive spring scale and loaded until buckling occured. The critical buckling load was recorded.

Finally, the type of coating was determined and rated in accordance with the discussion presented in the introduction of this section.

3. Results

The geometrical properties are summarized in Table 3. The alloy specification and properties are presented in Table 4. Table 5 indicates the relative resistance to bending, the experimentally determined buckling load, the flexural spring constant, and the ratings of the outer coatings.

Table 3 - Geometrical Properties of Tubing

Cane	Section	Length[1] L (inches)	Diameter D (inches)	Thickness t (inches)	Area Moment I (in.^{4})
1	all	full	.500	.050	.00181
2	all[2]	full	.500	.050	.00181
3	all	full	.500	.035	.00139
4	1[3]	7.9	.710	.015	.00198
	2	6.8	.625	.015	.00134
	3	6.6	.570	.015	.00101
	4	6.3	.515	.015	.000737
	5	6.0	.460	.015	.000520
	6	5.7	.405	.015	.000350
	7	5.3	.350	.015	.000222
	8	5.0	.300	.015	.000137
5	all	full	.500	.050	.00181
6	1	11.8	.500	.050	.00181
	2	13.3	.438	.050	.00117
	3	13.3	.325	.050	.000690
	4	12.0	.313	.045	.000350
7	1	20.6	.750	.050	.00677
	2	16.0	.625	.050	.00376
	3	15.0	.500	.050	.00181
8	1	20.5	.750	.050	.00677
	2	17.0	.625	.050	.00376
	3	15.0	.500	.050	.00181
9	all	12.9	.500	.070	.00224
10	1	10.3	–	.015	.00143[4]
	2	7.5	–	.025	.00157
	3	7.9	–	.025	.000935
	4	8.3	–	.020	.000377
	5	8.2	–	.020	.000163
	6	8.2	–	.040	.0000820

Notes: 1) These are the lengths used in all the calculations. They correspond to the exposed lengths of the sections with overlapping at the joints not included.

2) Handle not included.

3) Sections were considered as if they were circular.

4) Since the sections of the cane are tapered, a single area moment cannot be assigned. The values listed represent the average area moment which (in the interest of simplicity) were used in all calculations.

Table 4 - Alloy Specifications of Tubing

Cane	Material	Tensile Strength (psi)	Yield Point (psi)	Shear Stress (psi)	Young's Modulus (psi)	Notes
1	Aluminum 6061-T6	45,000	40,000	30,000	10×10^6	3
2	Aluminum 6061-T6	45,000	40,000	30,000	10×10^6	3
3	Aluminum 6061-T6	45,000	40,000	30,000	10×10^6	3
4	Brass[1]	-	-	-	16×10^6	4
5	Aluminum 6063-T832	42,000	39,000	27,000	10×10^6	5
6	Aluminum 6063-T832	42,000	39,000	27,000	10×10^6	5
7	Aluminum 6063-T832	42,000	39,000	27,000	10×10^6	5
8	Aluminum 6063-T832	42,000	39,000	27,000	10×10^6	5
9	Aluminum 6061-T6	45,000	40,000	30,000	10×10^6	3
10	Fiberglass[2]	30,000	-	-	2×10^6	6

Notes:

1) Because of the difficulty in contacting the manufacturer in West Germany, neither the alloy nor its hardness are known. The Young's Modulus given is typical of all brasses commonly available as tubing. But since the hardness is not known, no information as to the tensile strength or yield point can be ascertained.

2) The resin or type of glass mat are not known. The values shown are typical for fiberglass.

3) From Kaiser Aluminum Catalog, 1970. Has excellent corrosion resistance.

4) From Revere Copper and Brass Catalog, 1970. Maximum shear stress unknown.

5) From Kaiser Aluminum Catalog, 1970. Has excellent corrosion resistance and finishing characteristics.

6) From PPG Industries Catalog, 1970. Yield point and shear stress have no meaning for fiberglass.

Table 5 - Tubing Evaluations

Cane	Spring Constant (lbs/in)	Deformation Resistance	Buckling Load (lbs.)	Outer Covering Type	Outer Covering Rating
1	.60	1.00	55	Painted[1]	Fair
2	.82	1.00	55	Painted[1]	Fair
3	.46	.77	35	Plastic Adhesive	Good
4	.51	.15-.40[3] .80-2.00	-[2]	Chrome Plated	Excellent
5	.60	1.00	55	Polished Aluminum	Excellent
6	.38	1.00 .31	22	Adhesive[1] Plastic	Good
7	1.66	2.50 1.00	45	Polished Aluminum	Excellent
8	1.67	2.50 1.00	70	Polished Aluminum	Excellent
9	.74	1.24	60	Adhesive Plastic	Good
10	-[4]	.54 .09	6	Fiberglass	Good

Notes: 1) The last section from the handle is red anodized.

2) Specimen broken before test.

3) Since the yield point is not accurately known, the deformation resistance cannot be calculated. Given are the ranges that could be expected depending on the hardness of the tubing.

4) A calculation here is very difficult because of the tapered geometry of the sections and the uncertainty of the physical properties of fiberglass. However, a crude approximation reveals that this value is at least .05 lbs./in.

4. Discussion

a. Alloy

For the canes made from metal, there is very little difference between them. All of the alloys had good mechanical properties for this application. The reason the manufacturers use one alloy over another is for finishing charactertistics. Brass is easily chrome plated, so it's used in Cane 4. The only advantage 6063-T832 has over the 6061-T6 is that it has much better finishing characteristics. Thus, on the canes which had polished finishes the manufacturer opted for the former while on the others they used the latter.

b. Flexural Spring Constant

Canes 7 and 8 are rated far superior in this category with an equivalent stiffness coefficient varying from 200% to 300% above the rest of canes. However, this is done at the expense of adding additional weight to the cane. Canes 1,2,5 and 9 are rated next with a rate varying from 0.6 to 0.8 pounds per inch. We feel this is a very good compromise between rigidity and bulkiness of the cane.

Canes 3,4 and 6 are rated somewhat lower with a gradient from 0.4 to 0.5 pounds per inch. Cane 10 is rated last with a value of around 0.05 pounds per inch. (This calculation is at

best only crude because the physical constants of fiberglass are not well controlled and fall within a range, not at a specific value. Also, the approximations used in this calculation all tended to decrease the final value obtained. This result is probably much lower than the actual value. See the result by experiment in Section C.) This cane is obviously too flexible to transmit properly to the user.

c. Resistance to Deformation

Most of the canes rated about the same in this category with Canes 7 and 8 slightly better than the average and Canes 3 and 6 a little below. On the other hand, Cane 10 rated much lower than the rest, having only 10 - 50% the strength of the other canes.

d. Buckling Load

Again, Cane 10 rated very low in this category taking only six pounds of axial compressive force to cause the cane to buckle. This magnitude could easily occur should the cane strike a rigid wall while the user is moving quickly, rendering the cane useless.

The rest of the canes all had sufficiently high load requirements making it virtually impossible for the cane to fail in such a manner.

e. Outer Covering

Canes 1 and 2 had only a painted covering. Thus, they are prone to chipping and denting more than the rest of the canes. The others had either a plastic adhesive coating or the metal had a good finish.

C. Joints

1. Introduction

The joints are the most important aspect of the non-rigid cane, for it is the joints that enable the cane to disassemble and fold to a convenient size, and yet hold it rigidly together when it is fully assembled. It is how effectively the joints hold the cane together along with the ease these joints provide for extending and collapsing the canes that are the main concern of this section.

The joints on the canes may be conveniently divided into three categories: friction joints; straight joints; flared or tapered joints. In a friction joint, it is the frictional force between the sections of the cane that holds the cane in the extended position. We know from basic mechanics that the frictional force is equal to the product between the normal force and the coefficient of friction between the surfaces. Typical values for the friction coefficient are from 0.5 to 0.8 for metal on metal. This means that to get a high frictional force to hold the cane together higher normal forces are required. Thus, some sort of mechanism is usually needed so that these large forces can be created without imposing a hardship on the user. Because the user of the cane has to manipulate this mechanism the time required for opening and closing will suffer.

In order for these forces to be created each section of the cane must be in good contact with the next section. Therefore, there will be no looseness in the joints. Also, since the mechanism location is unimportant when it's tightened, the canes using the friction joints can be made adjustable.

In order to eliminate the mechanism that is required to make the friction joints work, another type of joint called the straight joint can be utilized. In this type of joint there male and female ends which are designed similar to that shown in Figure 4.

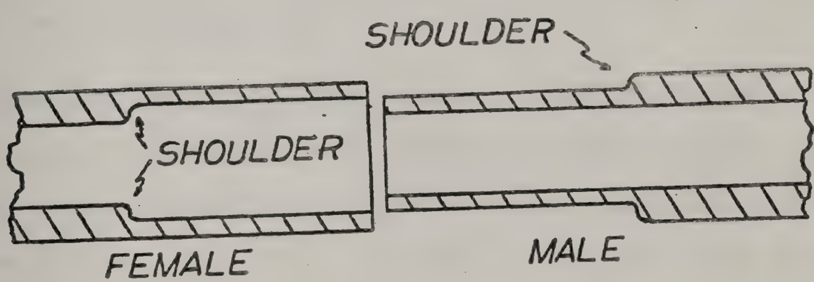


Figure 4 - Straight Joint

The male joint slides into the female counterpart. Ideally, the outside diameter of the male is exactly equal to the inside diameter of the female, preventing relative lateral motion. The shoulder, which could be on the male or female part of the joint,

prevents axial compressive motion. However, there is nothing that will hold the cane together if a tensile force is applied. So, a mechanism is needed to prevent this from happening. All of the canes that had this type of joint used an elastic cord to supply a compressive preloading to the tubing. In order to collapse the cane a tensile force greater than the preload has to be applied. An obvious conflict in design interest is readily seen here. Should the elastic be set for a high preload so that if the cane is accidently caught the user may dislodge it without collapsing the cane, or should the preload be low so that the cane is easier to collapse.

There are other problems with this design. First, since the clearance between the two portions of the joint is small, the two sections must be perfectly aligned before they will slide into each other. Secondly, in order to prevent joint looseness, the clearance between the male and female should be zero. But if it was zero, it would be impossible to slide the joint together. So, by providing the clearance needed to easily slide the parts together you must have joint looseness.

Another problem that this type of joint encounters is wear. If either or both portions of the joint should wear the clearance increases and the joint loosens. Thus, a straight joint loosens with increased use.

The last and most significant problem is burring. This is a small but sharp deformation on the edge of a piece of metal caused by pounding or hitting the edge against another surface. In the case of the cane it is the two sections hitting each other that causes the burring. Burring is detrimental for two reasons. First the sharp edges cause excessive abrasion to the inner elastic cord (see Section F). Secondly, if the burrs point toward the inside of the female, they could prevent the male from uniting with the female (see Figure 5).

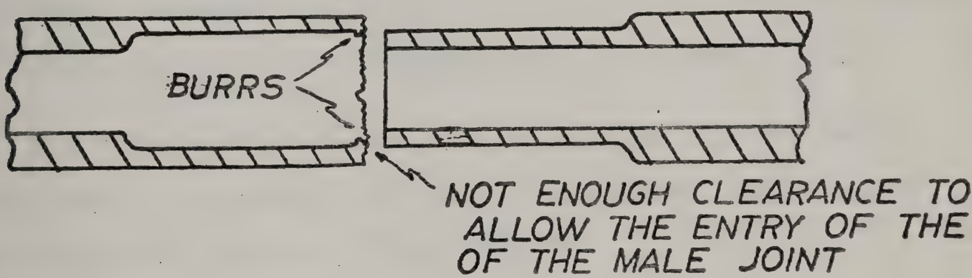


Figure 5 - Straight Joint Burring Problem

To solve some of the problems encountered with straight joints the flared or tapered joint may be employed. This type of joint is quite similar to the straight joint except that the joint is tapered (see Figure 6).

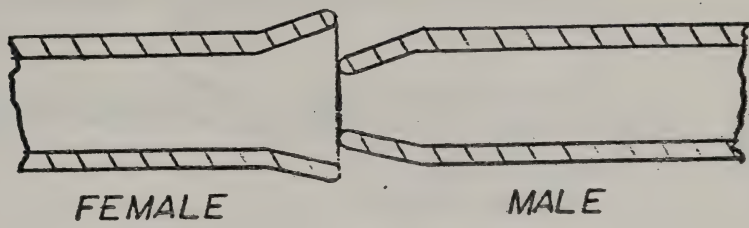


Figure 6 - A Tapered Joint

One obvious problem that this design solves is that there is no longer a need of precise alignment of the male and female in order to assemble the cans. As long as the joints are placed one inside the other the alignment will be automatic.

Also, the problem of wear is eliminated. If the metal should wear, the joints will just go in further to lock, but they will lock just as if they were new.

Furthermore, the problem of burring is no longer as critical as it is iwth the straight joints. Since these joints no longer require precise alignment, the chance of the edges of the two sections hitting each other is reduced, thus, the probability of burring is diminished. Also, if the largest inside diameter of the female is larger than the largest outside diameter of the male, then the burrs will not prevent the assembly of the cane (see Figure 7). Only Cane 5 took advantage of the feature.

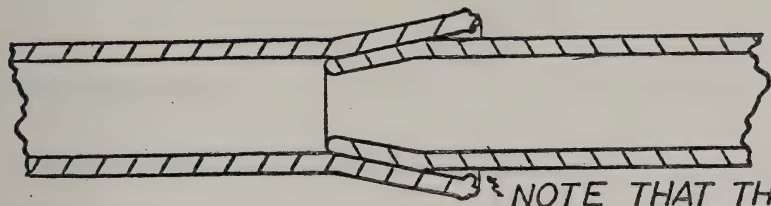


Figure 7 - Burring of Tapered Joint

However, like the straight joint, the tapered joint needs some sort of compressive preloading to hold it together. Most of the canes used an elastic inner cord. The burrs are just as detrimental to the inner elastic for the tapered joint as they are for the straight joint.

In addition to this common problem, the tapered joint will have a few problems peculiar to itself. First, it does not resist lateral deflection as well as the straight joint. In fact, the larger the taper the harder it is to resist the lateral motion. To overcome this problem a larger compressive preload must be applied causing the user to exert a larger force in order to collapse the cane.

The most difficult problem encountered with tapered joints is jamming. If a cane is held vertically and tapped gently on the floor, the joints are forced together creating excessive friction between the two sections of the joint. This, in effect, jams the joint making it virtually impossible to disassemble the cane. This is especially true if the taper is machined to close tolerances in order to eliminate joint looseness.

D. Tip

1. Introduction

The tip is the part of the cane with which the user has contact with the outside world. Thus, it can be considered the heart of the cane. It is with this in mind that we conduct a close examination of the cane tips to find out just how well they function and how long they last. There are two types of tips available. One is made from nylon while the other is of nickel plated steel.

Since one very important function of the cane tip is to allow the user to interpret the information of the reflected sounds made from tapping it, an investigation comparing the two types of tips is made. The test performed measured the sound (energy) level that was given off by a prescribed tapping motion. The louder the sound the farther it will travel before decaying to an inaudible level, thus, the more information gained about objects further away. To insure against bias, a machine was built to simulate a prescribed tapping motion and sound level readings were taken for all the canes tested (see procedure).

As important as the loudness of the sound is the spectral information of the noise produced. This is the "type" of sound heard. Obviously, the nylon tips will not sound the same as the steel tips. A spectral analysis would produce little useful information because the human hearing mechanism is highly individualistic. The spectral sensitivity varies greatly from

one person to the next. Thus, the individual user must make the choice with respect to type of sound desirable.

When a cane is moved back and forth by its user, the force necessary to slide the cane is proportional to the coefficient of friction. The friction coefficient is a function of the two materials involved, namely, tip and ground. Since the tip may contact an infinite variety of surfaces (concrete, asphalt, wood, tile, carpeting, ... etc.), it is impossible to assign each tip a single frictional coefficient. However, on smooth surfaces the nylon will have a coefficient of friction less than that of the nickel tip. On the other hand, on rough surfaces, such as concrete, the coefficient for the nylon tip may become greater than for the metal tip because it will alow the grit of the rough surface to dig in, thus, increasing friction. As in the case of sound type, the friction coefficient is highly individualized depending both on user preference (smooth or rough surface) and upon the type of use (indoors-outdoors, city-country, ... etc.) most encountered. Therefore, no further attempt has been made here to deal with the frictional coefficient associated with the cane tips. Furthermore, since our observations indicate that most cane users employ an off the ground tapping motion, the friction involved in walking with a cane cannot be considered as a primary design criteria.

An important criteria in evaluating any physical device is its expected life. Cane tips are subject to an extreme amount of abrasion. The most common modes of tip failure then would be due to wear. There are many factors affecting abrasive wear but the two primary ones are hardness and amount of material. Nylon is softer than nickel and steel. Thus, in equal amounts a nylon tip will wear much quicker than the metal tip. Close observation of the tips indicate that there is significantly more nylon used than steel so that the difference in type of materials is counterbalanced by the amount employed. Therefore, the two types of tips are rated approximately equal to each other in this area.

The only detrimental effect observed is the possibility of the tip getting caught or wedged in a crack or crevice. We assume here that the greater the area of the tip the less possibility for this type of occurrence. Henceforth, special attention is given to tip area in our evaluations.

2. Procedure

A machine was constructed to simulate a tapping motion (see Appendix G). Special care was taken to insure that the kinematic quantities of velocity and acceleration at the tip were identical for each cane tested. (Another, but less meaningful, procedure would be to insure that the kinetic energies of the canes before striking the ground were identical.) Each cane was

tapped on wood, concrete, and tile surfaces and sound level readings were recorded. The results indicate which canes sound loudest on each surface. No attempt was made to give any conclusive information about the sound level differences between the surfaces.

Finally, the tips were measured and weighed and appropriate results were recorded.

3. Results

The results are summarized on Table 11.

Table 11 - Cane Tip Characteristics

Cane	Loudness (dB) Concrete	Wood	Tile	Material	Area (in2)	Weight (oz.)
1	69	77	66	Nylon	.20	.3
2	74	78	68	Nylon	.20	.3
3	70	80	69	Nylon	.31	.5
4	70	83	67	Steel[1]	.48	1.0
5	69	79	67	Steel[1]	.47	.7
6	67	80	66	Steel[1]	.47	.6
7	70	79	66	Steel[1]	.47	.4
8	69	79	67	Steel	.47	.4
9	71	79	69	Nylon	.18	.3
10	66	72	63	Steel	.68	.4

Notes: 1) These canes are available with nylon tips, however, only the steel tips were evaluated.

4. Discussion

a. Sound Level

All the canes except for Cane 10 rated about the same in this category. It should be noted that at these levels the ear cannot distinguish the difference in the sound level between two signals if they are within 3 dB of each other. Therefore, it can be concluded that the tip material does not significantly affect sound level.

The reason Cane 10 is lower than the rest is that it is far lighter. Even though it converted the same percentage of kinetic energy to sound energy, its lower mass causes a lower sound level.

b. Material Selection

There are no outstanding differences between the nylon and metal tips. Since sound sensitivity and frictional coefficient depend on the individual, it is recommended that manufacturers provide an option. Canes 5,6,7 and 8 do offer a choice between the two types of tips.

c. Tip Area

Because of the importance of avoiding the tip from getting caught easily, it is surprising that the manufacturers of Canes 1,2,3 and 9 employ such small tips. Cane 10 is by far the largest

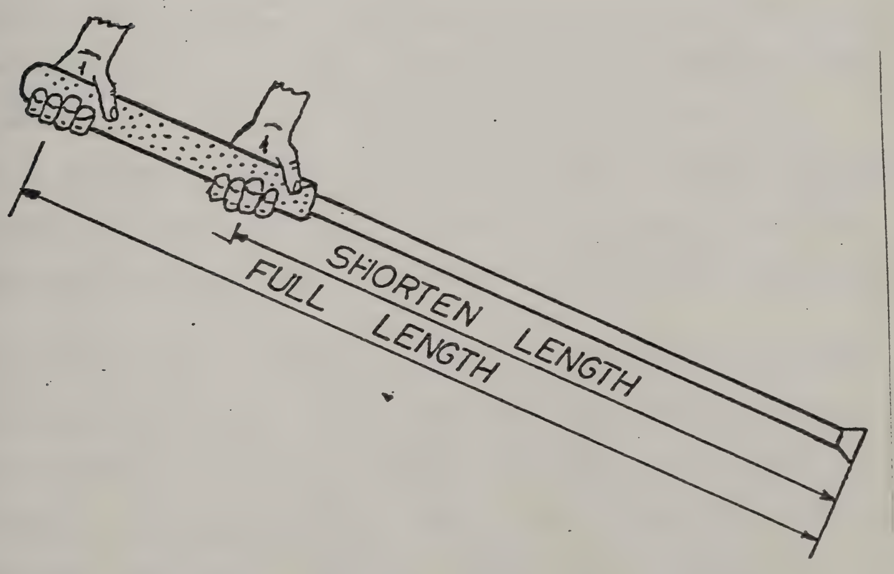
with Canes 4,5,6,7 and 8 next. We consider a good tip size to be about 3/4 inch in diameter. This yields an area of about .45 $in.^2$ which is large enough to prevent the cane from getting caught in most instances, and yet not too large to be cumbersome. Canes 1,2,3 and 9 all have smaller tips ranging in area from .2 to .3 in^2.

E. Handle

1. Introduction

The handle is important because it is with the handle that the user makes direct contact. The handle should be made as comfortable as possible since the cane may be employed for long periods of time. It should have good insulating properties so that in cold weather the hand is well protected. In addition, a moderately long handle provides an easy and quick means of adjusting the length of the cane. If the user wants a shorter cane, this is accomplished by grabbing the handle at the bottom.

Figure 11 - Use of Handle



On the other hand, if a long cane is desired, then the user may simply hold the handle near the top of the cane.

Another important characteristic of a good handle is the ability of the material to absorb water. If when the user perspires and the handle does not absorb the moisture, then the handle will become damp, uncomfortable and slippery.

2. Procedure

The comfort associated with each handle is a totally subjective quality. No attempt has been made to quantify this characteristic. Ratings are based on personal observation after a period of usage.

After the handles were removed from the canes, they were weighed and measured. Next, a two inch section was cut from each handle and dried in a 145° oven for two hours. The sections were then immediately weighed. Afterwards they were submerged in water for 24 hours. Finally, each section was weighed again and the percentage of water absorbed was recorded.

The insulating properties of the handles depend on the coefficient of thermal conductivity and the material thickness. Since for most plastics and rubbers the thermal conductivity coefficients are approximately equal, the thickness of the grip becomes the governing parameter. Since most handles were of varying thickness, an average value was recorded and a relative scale made and reported.

3. Results

The results for this section are shown on Table 12.

Table 12 - Handle Characteristics

Cane	Length (inches)	Weight (oz.)	Comfort	% H_2O Absorbed	Insulating Properties
1	4.6	1.6	Fair	.2	Excellent
2	8.2	4.6	Poor	0	Poor
3	11.0	2.4	Excellent	.5	Excellent
4	7.6	.3	Good	0	Fair
5	10.7	1.8	Very Good	.5	Good
6	10.7	1.8	Very Good	.5	Good
7	-	-	Good	0	Poor
8	4.6	1.1	Fair	.2	Fair
9	11.0	2.4	Excellent	.5	Excellent
10	-	-	Good	0	Fair

4. Discussion

There are basically two types of handles presently employed on the canes. Canes 1 and 8 had a bicycle grip while Canes 3,5,6 and 9 used a golf grip. The other canes either had no grip at all as on Canes 7 and 10, or they had a thin plastic coating over the metal tubing as on Canes 2 and 4.

The golf grips are superior in all categories and they are recommended for use on all the canes. There were two versions of golf grips, but the differences between them are minor. However, we were informed by the manufacturer of Canes 5 and 6 that they are in the process of switching to the slightly more comfortable grip used on Canes 3 and 9.

The bicycle grips are significantly inferior to the golf grips in all categories. Therefore, they are not recommended.

Canes 4,7 and 10 rate well with respect to comfort and length (we consider for canes without a grip the length to be that of the entire first section) but poor in water absorbancy and insulating properties. Since absorbancy and insulation only affect performance in adverse weather, these canes are acceptable in moderate climates.

Cane 2 is so uncomfortable to hold and use that it receives the poorest rating of all.

F. Inner Elements

1. Introduction

In canes 1,3,5 and 6 it is the inner elastic that is responsible for holding the cane in the extended position for utilization by the owner. Without this fastening device these canes would be merely separate pieces of hardware. It is therefore considered of paramount importance that these canes be designed to insure the longest possible life of the inner elastic.

In discussions with several manufacturers of elastic cords some general agreement was found as to the conditions and characteristics which affect cord life.

First, since the rubber inside the cord is not directly exposed to the outside elements, it makes little difference what type of rubber is employed in the manufacturing process. Therefore, no attempt has been made here to identify or separate the inner material.

Secondly, it doesn't matter what method is employed in fastening the elastic to the cane so long as it is done in such a manner that sharp edges do not cut into the cord.

Another factor in determining the life of the elastic cord is the amount of stretch it has when the cane is extended

in comparison to its undeformed length (axial strain). The greater the axial strain, the shorter the cane life. However, only very large differences in strain (about 40 to 50%) are needed before any difference in cord life will be noticed, and even this will be only a minor difference. Results for this are shown in terms of force-strain curves.

The single most important aspect of cord life is its resistance to abrasion. The most common form of failure is due to the rubbing of the cord against the sides of the tubing while the cane is being opened and closed, subjecting the outer coating to abrasive wear. Once the protective coating is completely worn through and the rubber is exposed it will not take long (usually a few openings and closings) before the rubber breaks rendering the cane useless to the owner. The resistance of the elastic to abrasive failure depends on two factors. The first is the type of material employed for the outer coating of the cord. The second is the ease that the joints have for burring while the cane is opened and closed (see Section C).

Three different materials are used by manufacturers for the outer coating. Polypropylene is considered best because of its resistance against abrasion and degradation due to exposure to the elements. Nylon is good in its abrasion and degradation resistance with a rating only slightly lower than

than polypropylene. Lease best is cotton with significantly lower resistance characteristics. Also, since cotton has a much lower tensile strength in comparison to polypropylene and nylon, it is more prone to failure under high tensile forces.

In addition to the elastic cords, two other fastening methods are utlized. A stainless steel cable is employed in the cable cane 2 while a nylon rope is used in the rigid fold cane 9. Both of these canes (2,9) were subjected to the same criteria as the previous canes with inner elastic (1,3,5,6).

2. Procedure

The materials employed for the inner elements were found by contacting the manufacturers. The tensile strength of the cords were tested by clamping one end and using a 50 pound spring gage to measure the axial force applied. The reading just before failure was recorded. If the full 50 pounds was reached and failure did not occur then the cord was considered more than adequately strong for the particular application here. Of course, the steel cable and nylon rope are substantially stronger than the elastic cords.

The force-deflection curves were plotted from information obtained by experiment (see Appendix H). The unstretched and stretched (cane fully extended) lengths of the cords and axial forces were recorded. The axial strains (change in length/ unstretched length) were computed.

Finally, the canes were very closely examined for adverse methods of fastening and resistance to abrasion. Important features were noted and ratings were made and reported.

3. Results

Table 13 summarizes the inner element characteristics and Figure 12 represents the axial force-strain curves.

Table 13 - Inner Elements Characteristics

ane	Coating Material	Tensile Strength (lbs)	Unstretched Length (inches)	Axial Strain	Fastening Method	Abrasive Resistance
	Double Coated Cotton	30	30	.58	Satisfactory	fair
	Plastic Sheath Steel Cable	over 50[1]	-	-	Unsatisfactory[2]	excellent
	Polypropylene	over 50	27	.71	Satisfactory	good
	Nylon	over 50	36	.36	Satisfactory	excellent
	Nylon	over 50	36	.42	Satisfactory	excellent
	Nylon Rope	over 50[1]	-	-	Satisfactory	outstanding

otes: 1) over 200 pounds.

2) small radius on the pin fastening cable to arm of handle (stress concentration)

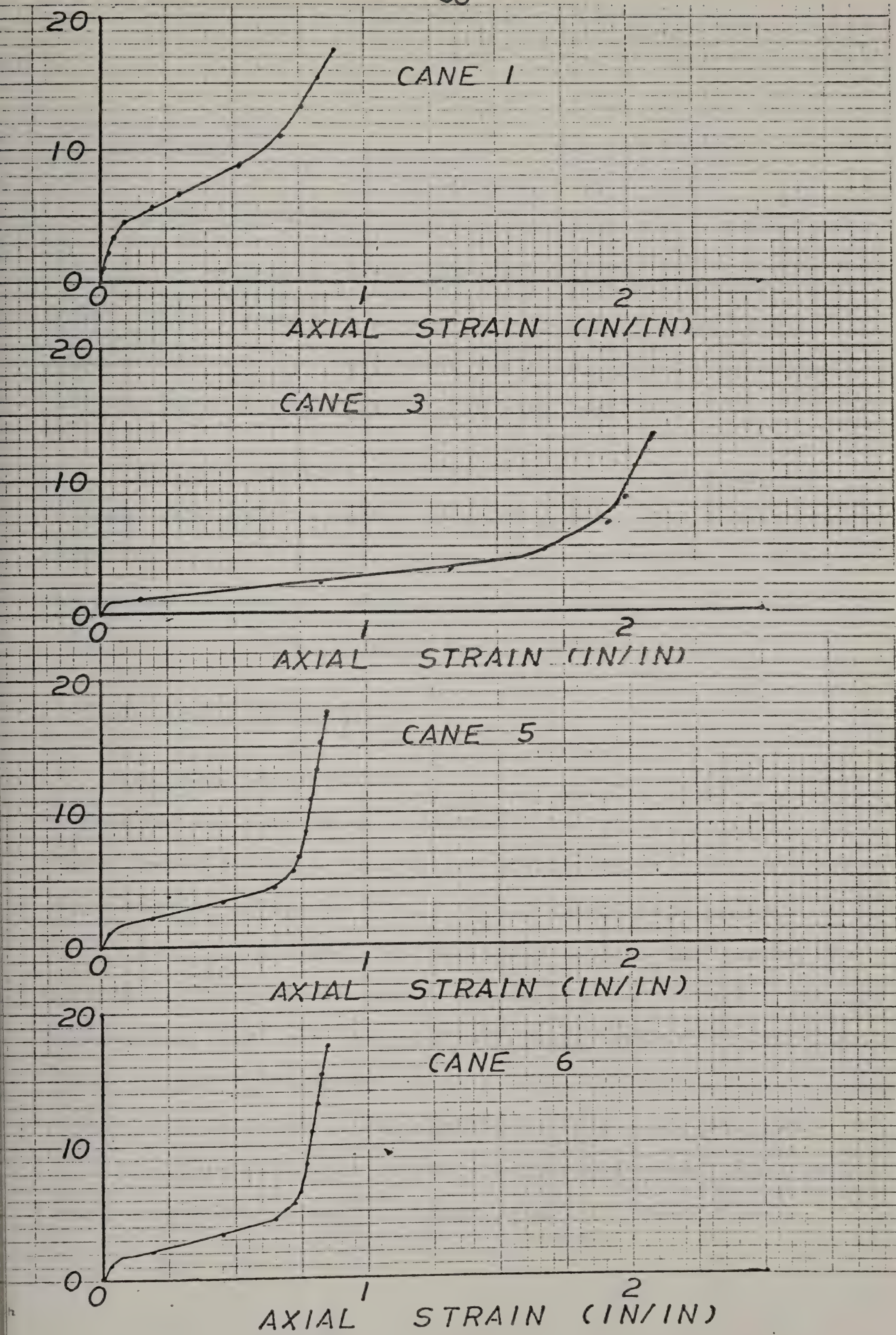


Figure 12 - Force-Strain Curves for Elastic Cords

4. Discussion

a. Tensile Strength

All of the canes tested had axial tensile strengths for their inner elements in excess of 30 pounds. Since this is considered more than sufficient for this type of application, all the canes are satisfactory in this area.

The inner elements for Canes 2 and 9 are outstandingly strong being able to resist over 200 pounds axial force. The cords for Canes 3,5 and 6 are excellent resisting well over 50 pounds of tension. Weaker but satifactory is the inner cord of Cane 1 with a tensile force limit of 30 pounds.

b. Axial Force-Strain

The axial force-strain curves are highly nonlinear (see Figure 12) but consist of essentially two linear regions. The first region is due to the action of the rubber alone, with the outer webbing adjusting itself to the appropriate length. In this transition between the two linear regions the webbing can no longer freely extend and it in addition to the rubber resists the applied load, and thus the stiffening effect. In the second linear region the webbing is fully extended and the tensile strength of the outer coating is responsible for the curve produced.

Also from Figure 12 we can see that the normal axial strain (cane extended) varies from about .4 to .7. Thus, from our

previous discussion, the cord life is only dependent on abrasion resistance.

Canes 3,5,6 all have the fully extended strain well within the first linear portion of the curve. Therefore, when the cane is collapsed, which increases the strain by .1 to .2, the point of operation will still be in the first linear region. Thus, there will be no stress developed in the outer coating.

Cane 1, on the other hand, has its fully extended strain in the transition region. Thus, when the cane is opened the operating point is placed in the second linear region. This places a stress on the cotton fibers when the cane is opened. This stress not only greatly increases the force required to open the cane, but it will also decrease the life of the cord through fatigue of the outer cotton layer.

c. Fastening Method

All canes except for Cane 2 had a satisfactory fastening method. Cane 2 had an extremely small radius on the wrist pin that fastens the cable to the lever arm in the handle. This will cause a tremendous stress concentration and premature breakage. (As noted in Section H extensive fraying did occur after only a few hundred closings.) Since the cable does not rotate about the bottom pin, the small radius there is not critical, but a larger pin is strongly recommended.

G. Safety

1. Introduction

In addition to an evaluation of strictly mechanical properties of the canes, several other aspects relating to the canes were investigated, the first being that of safety. This section is concerned with reporting any safety hazards that were observed and any features that would make one cane safer to use than another.

When a visually impaired person is walking outdoors at night, it is considered of utmost importance that the cane should be plainly visible. This will accomplish two objectives. First, it identifies the user as being visually impaired so that more than the usual amount of caution may be employed. Second, it is important that people be aware that there is something being utilized by the blind person so as to provide more than the usual clearance necessary in order to avoid hitting the cane or its user. In order to facilitate visibility at night some canes employ a reflective coating on the cane surface. We consider this a very important safety feature. Instead of a reflective coating a few of the canes have a polished metal surface which increases visibility but not to the extent of that due to a reflective coating. Several canes provide only a white surface to aid visibility.

In the canes which employ inner elastic cords to hold them together in the extended position, a very good safety feature is a system of two independent cords. In this way, if one band breaks, the other will still hold the cane in place.

A wrist elastic is also considered to be advantageous. It provides a means of keeping the cane in the folded position (this does not apply to Canes 4,7,8,10). Also, if the cane is jarred from the hand, the wrist elastic makes it impossible to lose contact with the cane and facilitates easy recovery. Without a strap the job of recovery could be very difficult. On the other hand, the wrist elastic should be flexible enough to acommodate cases of violent jarring of the hand.

There were several safety hazards that were observed. In Cane 2 there seems to be a very good possibility of pinching the hand on the leverage mechanism. This may not be too serious after a familiarization period, but it remains as a definite hazard.

Cane 9 has a peculiar problem. When it is fully extended the excess string may get caught and cause a problem. However, this excess string may be used to an advantage. It could be looped around itself (see Figure 14) and be used as a wrist strap (no mention in user's manual).

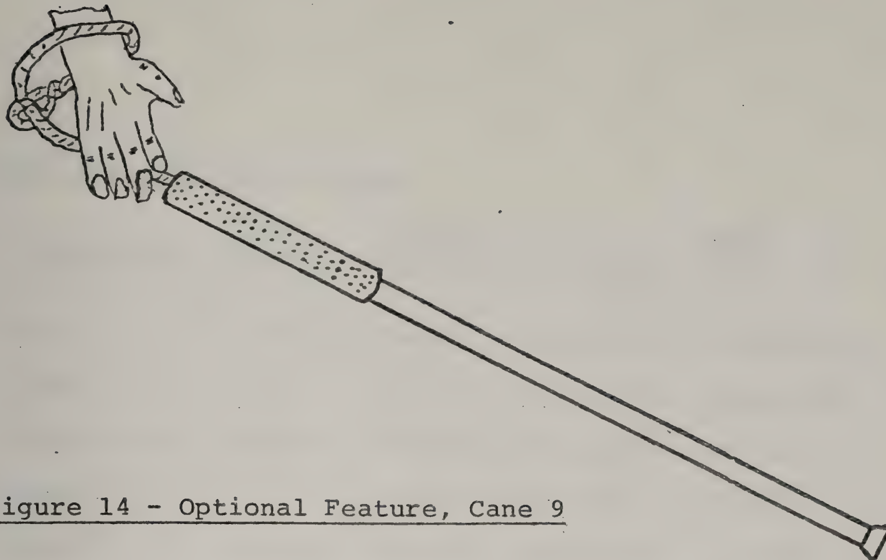


Figure 14 - Optional Feature, Cane 9

Of course, using a rigid cord in this manner could be dangerous should the cane be suddenly pulled from the user.

Another problem observed is the possiblity of the tip falling off. After an examination of each cane this possiblity was noted and indicated in the results.

The last safety hazard noted is the possibility of accidental collapse or other unintentional length adjustment. These are listed in the results and the reasons given.

2. Results

The results are listed in Table 14.

Table 14 - Safety Features

Cane	Visibility	Inner Elastic	Wrist Strap	Collapse	Loose Tip	Miscellaneous
1	Fair [1]	Single	No [5]	Impossible	Impossible	-
2	Fair [1]	-	No	Impossible	Impossible	Handle pinches.
3	Excellent [2]	Single	Elastic	Impossible	Unlikely	-
4	Good [3]	-	Plastic	Possible	Likely	-
5	Good [3]	Double	Elastic	Impossible	Impossible	-
6	Excellent [2]	Single	Elastic	Impossible	Impossible	-
7	Good [3]	-	No	Impossible	Impossible	-
8	Good [3]	-	Elastic	Impossible	Impossible	-
9	Excellent [2]	-	No	Impossible	Impossible	Rope as wrist strap
10	Fair [4]	-	No	Probable	Likely	-

Notes: 1 - White paint.

2 - Reflective coating.

3 - Polished metal.

4 - White fiberglass.

5 - The elastic provided holds together collapsed cane, but it cannot be wrapped around the wrist.

4. Discussion

a. Visibility

It is important that the canes be visible at night. To accomplish this Canes 3, 6 and 9 have a reflective coating on the tubing. Another approach used on Canes 4,5,7 and 8 is polished metal which gives acceptable visibility, but it is not as good as the reflective coating. A white exterior as employed on Canes 1,2 and 10 is better than nothing but less effective than the previous approaches.

b. Inner Elastic

Cane 5 has a system consisting of two independent elastic bands holding the cane together. This is an excellent feature in case one band breaks the cane can still function. Canes 1,3 and 6 employ a single cord only.

c. Wrist Strap

Canes 3,5,6 and 8 employ elastic wrist straps which can be readily utilized in the collapsed position for folding the cane and the extended position for recovering the cane. Cane 4 utilizes a plastic strap which is not as good as the wrist elastic. Canes 1,2,7,9 and 10 use no strap at all. We strongly recommend wrist elastics on all canes.

d. Safety Hazards

Cane 2 has a lever mechanism which could pinch the hand. The tips of Canes 4 and 10 are very likely to fall off. There is a possibility of the tip on Cane 3 coming off if it gets caught. Cane 10 is prone to accidental collapse. Even though the instructions of Cane 4 claim that it's adjustable, the cane easily deviates in length when the user does not have it fully extended.

H. Serviceability

1. Introduction

In addition to the safety features another nontechnical feature that was investigated was serviceability. This is defined as the ease with which the owner could repair a broken cane assuming that the replacement part is readily available.

User serviceability is considered to be a very important but not essential cane feature. However, obtaining the replacement part is just as important as the ease of replacing it. Unfortunately, attempts to gather such information were in vain.

In rating the canes for user serviceability, the most emphasis was placed on the ease of replacing the tip, for it is believed that the tip will probably be the part of the cane to receive the most wear and be the element in need of replacement first. Next, emphasis was placed on the ease of replacing the inner element (if such a device is used), because we consider it to be the next element to need replacement. The tubing and handle are not as important because they will long outlast the tip and inner element. These rather strong portions would only need replacing if they were subjected to severe conditions through some accident. It is felt that if the forces involved are so extreme as to bend or deform these parts a severe amount of other damage would occur so as to render the cane useless and impossible to fix.

Also included is the serviceability of any parts which may be peculiar to a particular cane.

2. Procedure

Each cane was individually and fully disassembled and reassembled. The procedure was noted along with comments as to the ease with which it was accomplished.

3. Results

Appendix I gives a detailed description for replacing cane components. Table 15 is a summary of the relative ratings for each cane in individual categories as well as overall. An excellent rating was given if no tools or mechanical ability are required. A good rating was given if the component could be replaced by someone with only a limited amount of mechanical ability using the simplest of tools. A fair rating was employed if the procedure required a moderate amount of mechanical ability and the use of fairly complicated tools. Poor was given when a complicated procedure was necessary or another portion of the cane had to be destroyed in order to replace the part.

4. Discussion

a. Tip Removal

All canes except Cane 1 rated well in this area. The manufacturer of Cane 1 for some unknown reason riveted the tip

to the last section. This requires the rivet to be drilled out before the tip can be removed.

b. Inner Element Replacement

Canes 1,3,5 and 6, having elastic inner elements, rated poorly in this category. In order to replace the elastic the handle must be removed (destroyed), thus, requiring the user to replace the elastic and the handle. This is considered poor design by the manufacturer.

In both Canes 2 and 9 the inner element could be easily user serviced.

c. Handle Removal

All handles could be easily removed once they are slit along the axis of the cane.

d. Tubing

Tubing replacement is considered fairly easy for all canes except Cane 1. Either the handle must be removed or the user must have a reasonable amount of mechanical ability to manipulate the elastic cord from the tip end.

e. Overall

With the assumption that replacement parts are no problem, Cane 10 is by far the easiest to service, requiring no tools or special skills.

Canes 2,7,8 and 9 rate lower because they require some tools to be able to service them. However, anyone with simple tools would be able to service these canes.

Canes 3,5 and 6 are rated only fair because of the necessity of removing the handle in order to replace the inner elastic. Cane 1 is rated poor because both the tip and elastic are difficult to replace. Except for the tip replacement, Cane 4 is not user serviceable.

I. Durability

1. Introduction

To test the durability each cane was subjected to 500 opening and closing cycles. Assuming an average of three cycles a day this would simulate about five months of service to the average cane user. Since only one of each type of cane was tested, more accurate results can only be obtained by using many canes of each type using statistical analysis to interpret the results.

However, most of the forms of failure observed were predicted for each cane in the previous sections. There were few surprises. The only important aspect that must be stressed is that without a more rigorous approach using many more samples the expected time when failures would occur cannot be predicted with any degree of accuracy.

2. Procedure

Each cane was opened and closed 500 times. Afterwards they were all disassembled and each element of the canes was examined. The comments about these investigations were recorded and reported.

3. Results

A summary of each test result follows:

Cane 1

As the number of cycles increased, the force required to pull apart each joint generally seemed to decrease. This is attributed to the paint wearing off. However, at about 200 cycles a burr appeared at one of the joints. With the elastic being cotton coated, it did not take long for it to fray and eventually break on the 260^{th} cycle.

Cane 2

As the number of cycles increased the top joint began to stick but not to an extent that it required an abnormal force to pull it apart. The pivots between the handle and the lever show an extensive amount of wear with the holes quite elongated. This is not considered a serious drawback. When there isn't sufficient tension in the cable because the holes become elongated, all that is required is a simple cable adjustment to put the tension back.

It was also noted that the plastic tubing over the steel cable showed signs of abrasive wear but considering the thickness of the tubing this was not considerable as to be an excessive amount of wear. The worst problem with this particular cane was due to the extremely small diameter pin used to connect the cable to the lever in the handle. As was predicted in the inner elastic section of this report, extreme fraying did exist at this point in the cable, and the cord will probably break very shortly if it is continued to be opened and closed.

Cane 3

With the relatively thin metal used in the tubing (.035 inches) he female joints are more prone to burring than the other canes. his was indeed observed. Because of this excessive burring the lastic frayed at the joints. It is our belief that the elastic ill continue to fray and that within another 1000 cycles the elastic ord will fail.

Other less serious observations were that the lower joint ecame more difficult to open as the number of cycles increased, ut this is not excessive. The reason for this is unknown. Perhaps t was accidently dented while it was tested. The nylon string which ttaches the elastic to the cane was defectively tied and broke after he 210^{th} cycle. This is probably a defect in this particular cane nd we did not discredit the general design of the cane.

Cane 4

The extremely thin metal in this cane caused many problems. ecause of its relatively complicated cross section and joint arrange- ent, any slight bend in the tubing will cause problems. This did ccur. Even though care was taken while the cane was opened and losed it only took 100 cycles before the joints began to become arder and more difficult to operate. After 200 more cycles the hird joint from the handle became so bent that the locking mechanism o longer operated. In addition each locking button showed an xtensive amount of wear and we judge it to have only a limited life about 1500 cycles) before it becomes nonfunctional.

Cane 5

The finish on this cane was such that the metal would actually rub off on the hand of the user when operating this cane for just a few cycles. This will not, of course, affect the durability of the cane, but the user may find it unpleasant.

Because of the thick tubing (.050 inches) and the excellent deburring job done by the manufacturer, there was very little additional burring, thus, the nylon showed practically no fraying at all.

There were a few times (15/100) where the joints stuck together and more than the usual force was required to open the cane. Also, the force required to open the cane increased with the number of cycles. These phenomenon can be attributed to the very slight burrs that did exist. Even though these burrs were small and dull enough to prevent the cord from fraying, we feel that they were the cause of the tightening of the joints with increasing cycles.

Cane 6

Again because of the excellent deburring job by the manufacturer the nylon cord showed only the slightest signs of abrasive wear. However, due to the joint design, the slightest burr on the inside of the female section will prevent the male

section from entering, thus, preventing the cane from opening. This phenomena was experienced on the 327^{th} cycle. The cane was disassembled and the burr was filed off. The cane was assembled and no further problem occurred for the remainder of the 500 cycles.

Canes 7 and 8

As was the case with Cane 5, the surface metal rubbed off on the hand while opening and closing the cane. Again this is considered only an inconvenience to the user and not detrimental to the cane. With increasing use the joints of these canes loosened. As the lock is engaged by turning the tubing, the brass lock rides up on the tapered pin and wedges against the inner wall of the outer tubing. The twisting motion is transferred from the tubing to the tapered pin through the wrist pin. What happened was that wear occured at the holes provided for the wrist pin. Because of this wear the tapered pin was no longer securely fastened to the tubing and caused the joint to loosen.

It should be noted that even though these joints loosened, the amount is comparable to the looseness in the joints of most of the other canes when they were new (see Section C).

Cane 9

This cane showed no signs of wear either on the metal or on the nylon rope. Also, there were no signs of burring apparent

on either the male or female portions of the joint. In fact, there was no way of differentiating between the cane before or after the 500 cycles. Only the bottom joint stuck occasionally (5/100).

Cane 10

This cane came through the test perfectly. Opening the cane by pulling on the tip may cause it to come off because it is only a friction fit. On the other hand, the tip is easily replaced. However, if the cane is opened as designated, even this problem does not exist.

4. Ratings

Table 16 indicates the ratings for the canes on their relative durability. It is based on their performance during the 500 opening and closing cycles. Not only the number of problems were considered, but how detrimental each problem would be to the further use of the cane. Furthermore, consideration was given to whether the problem would be typical for the cane type or if it was just a special case.

Finally, it should be noted that these ratings are only for predicting how long a cane would last by opening and closing it. It makes no reference to the other modes of failure. These were covered in the previous sections.

Table 16 - Cane Durability

Cane	Durability Rating
1	Not Recommended
2	Not Recommended
3	Recommended
4	Not Recommended
5	Highly Recommended
6	Recommended
7	Highly Recommended
8	Highly Recommended
9	Highly Recommended
10	Highly Recommended

5. Discussion

Canes 5,7,8,9 and 10 suffered only insignificant degradation from this simulated five months of service. Therefore, these canes will probably last a few years, barring any catastrophic modes of failure.

Canes 3 and 6 are rated somewhat lower because they had burring problems. In the case of Cane 3, the burrs caused excessive abrasion to the inner cord, thus, decreasing life expectancy. In the case of Cane 6, the burrs prevent the joints from operating correctly. In order to use this cane further, the burrs have to be removed, an operation that needs some mechanical ability. Without further testing, we expect these canes to last about a year.

Finally Canes 1 and 4 broke before the estimated five months and Cane 2 had signs of major fraying of the steel cable. These forms of failure are considered to be a direct function of cane design. Since the expected life of these canes are less than a year, they cannot be recommended for use.

PART 3: CONCLUSIONS AND SUMMARY

A. Recommendations.

B. Future Work.

C. Conclusions.

A. Recommendations

Cane 1: Overall design modification necessary.

- Larger tip required.
- Change handle (from bicycle to golf grip).
- Inner cable modification (material, force-strain working region).
- Use elastic wrist strap.
- Do not rivet tip to cane.
- Improved serviceability required.
- Better exterior finish necessary.

Cane 2: Overall design modification necessary.

- Larger tip required.
- Handle modification (uncomfortable, pinches).
- Increase wrist pin radius to reduce stress concentration (where cable fastens to lever arm in handle).
- Use elastic wrist strap.
- Improve outer coating.

Cane 3:

- Improve inner element serviceability.
- Larger tip required.
- Eliminate possibility of tip being forced off.

Cane 4: Overall design modification necessary.

- Eliminate loose tip possibility.
- Change strap from plastic to elastic.

Cane 5:

- Improve inner element serviceability.

Cane 6:

- Improve inner element serviceability.

Cane 8:

- Change handle from bicycle to golf grip.

Cane 9:

- Larger tip required.
- Use elastic wrist strap.

Cane 10:

- Elminate loose tip possibility.
- Eliminate the probability of accidental collapse.
- Use elastic wrist strap.

B. Future Work

The following items represent areas where further work would be useful:

1. Increased Sampling and Cycles.

A limited test program was carried out using one cane of each type (one sample) subjected to 500 opening/closing cycles (approximately five months of service). The results reported for joint looseness and effectiveness, ease of opening and closing, and durabiity are limited to these constraints. Although much effort has been made throughout to determine whether the results were characteristic of the cane type or a fluke occurrence for the single sample, increasing the number of canes in each category and the number of test cycles would increase the accuracy and reliability of the findings. We estimate that three canes of each type subjected to 1500 cycles would be adequate and much more representative of the canes involved and actual conditions.

2. New Designs

A complete literature and manufacturer search would enable the observer to combine all existing schemes for non-rigid cane design in order to produce one or several canes with optimum mechanical characteristics. Much effort has been put forth here to point out features which are better than others within the confines of those employed on the ten canes evaluated. No attempt has been made to suggest new or other ideas and coordinate them with the features of the canes tested. For instance, the

collapsible canes employed by magicians have excellent characteristics with respect to collapse time, weight and compactness. Modification of existing canes to accommodate such features could be useful. Furthermore, in search of new ideas, we need not limit ourselves to the specific area of investigation. Many important and useful ideas and inventions are often transformed from other fields of study. There are numerous mechanical devices, gadgets, and mechanisms used in practice that may apply equally well to collapsible cane design.

3. Comparison of "Mechanical Evaluation" and "Field Survey."

Most useful of all is a coordination between the results of this evaluation (technical - unbiased) with the results from the field (practical - biased). It would be worthwhile to have both technical (familiar with cane mechanics and mechanical evaluations) and nontechnical personnel participate in this combined analysis of the canes.

C. Conclusions

Cane 1: Not Recommended.

- Uncomfortable to hold.
- Hard to open.
- Contains loose joints.
- Durability problems.
- Not user serviceable.
- Prone to surface chipping and scraching.

Cane 2: Not Recommended

- Uncomfortable handle.
- Very short life.
- Prone to surface chipping and scratching.
- Too small tip.
- No joint looseness.
- Inner element easily serviced.

Cane 3: Highly Recommended.

- Weaker of the metal canes.
- Rated well except for serviceability.
- Excellent handle.
- Excellent night visibility.

Cane 4: Not Recommended.

- Permanent deformation problems.
- Loose joints.
- Short expected life.
- Not user serviceable.
- Safety problems.

- Excellent collapse size.

<u>Cane 5:</u> Highly Recommended.

- Rated well except slightly difficult to open and close.
- Excellent handle.
- Excellent durability.
- Outstanding system of two independent elastic bands holding cane together.

<u>Cane 6:</u> Recommended.

- Lightest and weakest metal cane.
- Loose joints.
- Durability problems.
- Excellent handle.
- Excellent night visibility.

<u>Canes 7 and 8</u>: Recommended.

- Extremely strong.
- Excessively heavy.
- Too long when collapsed.
- Uncomfortable handles.
- Too much time to open.
- Excellent durability.

(These canes are strong and heavy requiring much user effort. They represent a good compromise between a rigid and a non-rigid cane possessing major characteristics of each. They are very rigid, but they collapse. These canes are excellent for rugged outdoor use by adept and agile individuals.)

<u>Cane 9:</u> Recommended.

- Joints stick.
- Slightly heavy.
- Excellent handle.
- Excellent night visibility.
- Rope may be used as wrist strap.
- Inner element easily serviced.
- Excellent durability.

<u>Cane 10:</u> Highly Recommended.

- Extremely compact.
- Excellent joint design.
- Very light weight.
- Extremely weak mechanical properties.
- Large and bulky tip.
- Easily serviced.
- Excellent durability.

(This cane is ideal for light indoor use with no adverse external conditions. It will easily break when bent by transverse or axially compressive forces. The big tip provides a good safety feature, and it is so bulky that the fulcrum of the cane is close to the center or midpoint.)

Appendixes

A. Cane Mechanics.

B. Relative Transverse Resistance to Permanent Deformation.

C. Cane Loading.

D. Equivalent Flexural Spring Constant.

E. Cane Joints

F. Maximum Transverse Load.

G. Simulated Tapping Machine.

H. Axial Force-Strain for Elastic Cords.

I. Replacing Cane Components.

Appendix A - Cane Mechanics

Consider the cane with forces as indicated in Figure A.

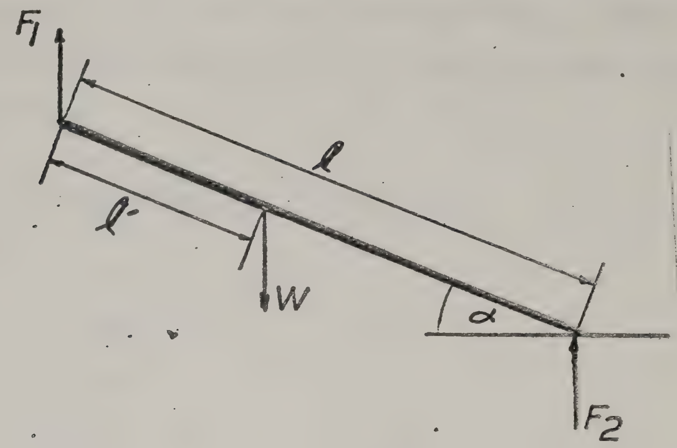


Figure A - Cane Forces

1. Tip-Rotation-Ratio

R = Actual Torque/Maximum Possible Torque

$= W \ell' \cos\alpha / W \ell \cos \alpha = \ell'/\ell$

2. Tip-Weight-Ratio

For moment equilibrium about the top of the cane

$W \ell' \cos \alpha = F_2 \ell \cos\alpha$

or

$R = F_2/W = \ell'/\ell$

Appendix B - Relative Transverse Resistance to Permanent Deformation

Using Equations (2), (3) and (4) and Table 3 and 4, we find that the bending moment which causes permanent transverse deformation to be

Cane	Bending Moment (inch-pounds)
1	289.6
2	289.6
3	224.4
4	-
5	289.6
6	289.6 (1/2 inch tube) 89.7 (5/16 inch tube)
7,8	722.1 (3/4 inch tube) 289.6 (1/2 inch tube)
9	358
10	157 (for largest tube) 27.3 (for smallest tube)

By normalizing everything to Cane 1 we deduce the relative resistance to transverse deformation (see Table 5, Section B).

Appendix C - Common Loading Situation

It is assumed that the most common loading situation encountered by a cane user is shown by Figure C. If the ends are approximately pinned, the maximum bending moment would exist at the point of application of the load. Since the load would normally be applied close to the tip, the maximum bending moment would be resisted by the smaller section yielding a lower relative ease of transverse deformation rating.

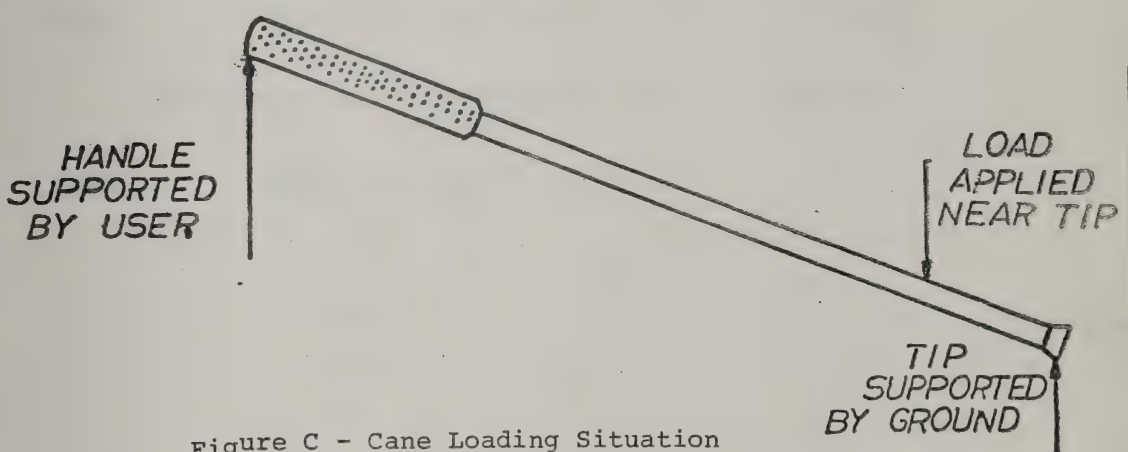


Figure C - Cane Loading Situation

Appendix D - Equivalent Flexural Spring Constant

1. Canes with Constant Sections

The spring constant is computed from the well known formula in mechanics of materials

$$k = 3EI/L^3 \qquad (D1)$$

where E = Young' modulus.

I = Second Area Moment of Inertia for the Section.

and L = Length of the Cantelever Beam (45 inches).

Inserting values from Tables 3 and 4 we obtain

Cane	Spring Constant (pounds/inch)
1	.60
*2	.82
3	.46
5	.60
9	.74

Note: * - Even though the tip did extend 45 inches beyond the edge of the table, the length was taken to be 40.5 inches. The reason for this is that the strength of the handle is so great that it in effect placed the fixed point beyond the table edge (see Figure D1).

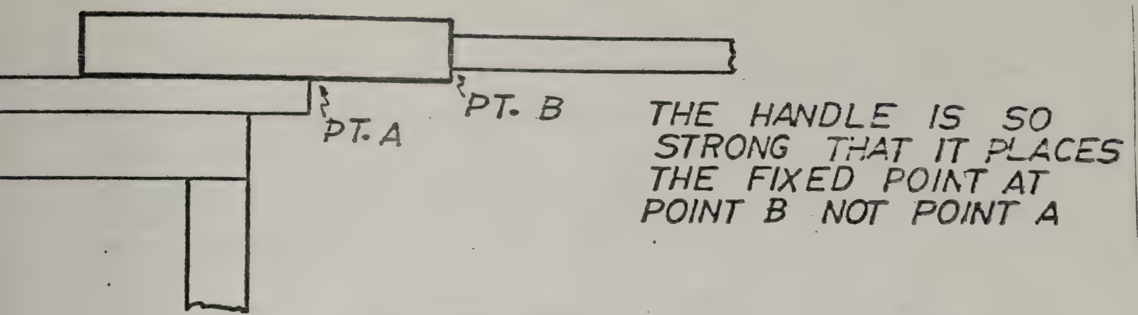


Figure D1 - Beam Length for Cane 2

2. Canes with Variable Sections

We assume the beam shown in Figure D2.

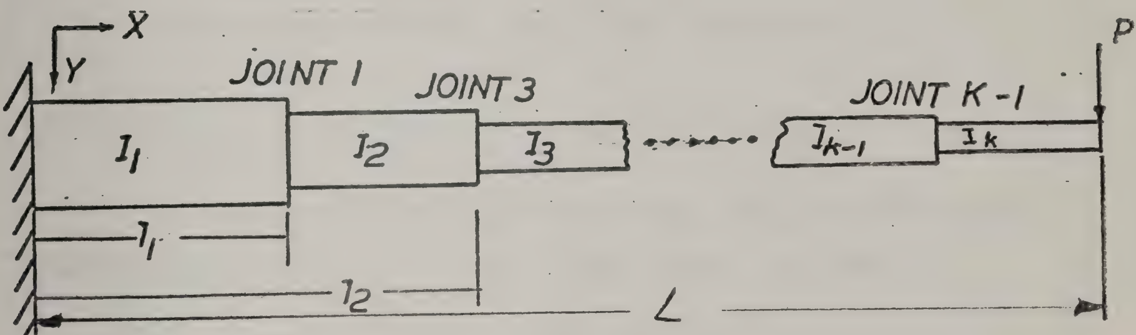


Figure D2 - Beam with Variable Section

We know from the Euler-Bernoulli Equation for the bending of a beam that

$$\frac{d\theta}{dx} = \frac{d}{dx}\left[\frac{dv}{dx}\right] = \frac{-M}{EI} \qquad \text{(D2)}$$

where v = transverse deflection

θ = slope

M = bending moment = $-P(L-X)$

E = Young's modulus

and I = the second area moment of inertia of the section.

Integrating Equation (D2) once for portion n yields

$$\theta = \frac{dv}{dx} = -\frac{P}{EI_n}\left[LX - \frac{1}{2}X^2\right] + C_N \qquad \text{(D3)}$$

To evaluate C_n we know that any any joint n the slope must be continuous (the same on both sides), so that

$$\frac{-P\ell_n}{EI_n}\left[L-\tfrac{1}{2}\ell_n\right]+C_N=\frac{-P\ell_n}{EI_{n+1}}\left[L-\tfrac{1}{2}\ell_n\right]+C_{N+1}$$

which means that

$$C_{n+1}=C_n-\frac{P\ell_n}{E}\left[\frac{I_{n+1}-I_n}{I_nI_{n+1}}\right]\left[L-\tfrac{1}{2}\ell_n\right] \quad (D4)$$

Since the slope at the wall equals zero, then $C_1 = 0$.

Integrating Equation (D3) yields for portion n

$$V=-\frac{P}{2EI_n}\left[LX^2-\tfrac{1}{3}X^3\right]+C_nX+D_n \qquad \text{(D5)}$$

To evaluate D_n we know that at any joint the deflection must be continuous (the same on both sides), so that

$$\frac{-P\ell_n^2}{2EI_n}\left[L-\tfrac{1}{3}\ell_n\right]+C_n\ell_n+D_n=-\frac{P\ell_n^2}{2EI_{N+1}}\left[L-\tfrac{1}{3}\ell_n\right]+C_{n+1}\ell_n+D_{n+1}$$

which means that

$$D_{N+1}=D_n-\frac{P\ell_n^2}{2E}\left[L-\tfrac{1}{3}\ell_n\right]\left[\frac{I_{n+1}-I_n}{I_nI_{n+1}}\right]+\ell_n\left[C_n-C_{n+1}\right]$$

Substituting in Equation (D4) gives

$$D_{N+1}=D_n-\frac{P\ell_n^2}{E}\left[\tfrac{1}{3}\ell_n-\tfrac{1}{2}L\right]\left[\frac{I_{n+1}-I_n}{I_nI_{n+1}}\right] \qquad \text{(D6)}$$

Since there is no deflection at the wall, $D_1 = 0$.

The spring rate is equal to the applied force divided by the corresponding deflection. This deflection is determined from Equation (D5) with X = L and C_k and D_k found from Equations (D4) and (D6). The results are as follows:

Cane	n	L_n (in.)	I_n (in.4)	C_n (rad.)	D_n (in.)	k (lbs./in.)
6	1	6.4	.00181	0	0	.38
	2	19.7	.00117	.008	-.025	
	3	33	.00069	.049	-.393	
	4	45	.00035	.182	-2.156	
7,8	1	14	.00677	0	0	1.66
	2	30	.00376	.006	-.041	
	3	45	.00181	.032	-.364	
4	1	3.3	.00198	0	0	.51
	2	10.1	.00134	.002	-.004	
	3	16.7	.00101	.008	-.033	
	4	23	.000737	.022	-.142	
	5	29	.000520	.050	-.419	
	6	34.7	.000350	.101	-1.049	
	7	40	.000222	.200	-2.405	
	8	45	.000137	.375	-4.967	
10	1	4.9	.00143	0	0	.05
	2	12.4	.00157	-.007	.016	
	3	20.3	.000935	.098	-.595	
	4	28.6	.000377	.658	-5.727	
	5	36.8	.000163	2.186	-24.195	
	6	45	.000082	5.152	-66.187	

Appendix F - Maximum Transverse Force

Equation (3) when applied to Figure 3 becomes

$$P_{max.} = \sigma_{yp} \; I/Lr \qquad \text{(F)}$$

where σ_{yp} = yield point stress for the material.

I = second area moment of inertia of the section.

L = length of the beam (45 inches).

r = outer radius.

For the canes with constant sections (Canes 1,2,3,5 and 9), the maximum transverse forces are computed directly from Equation (F). For canes with variable section (Canes 4,6,7,8 and 10), Equation (F) must be applied at each joint. A sample of this follows and all the results are compiled in Table 9 of Section 2C.

Figure F shows all the details for Cane 6.

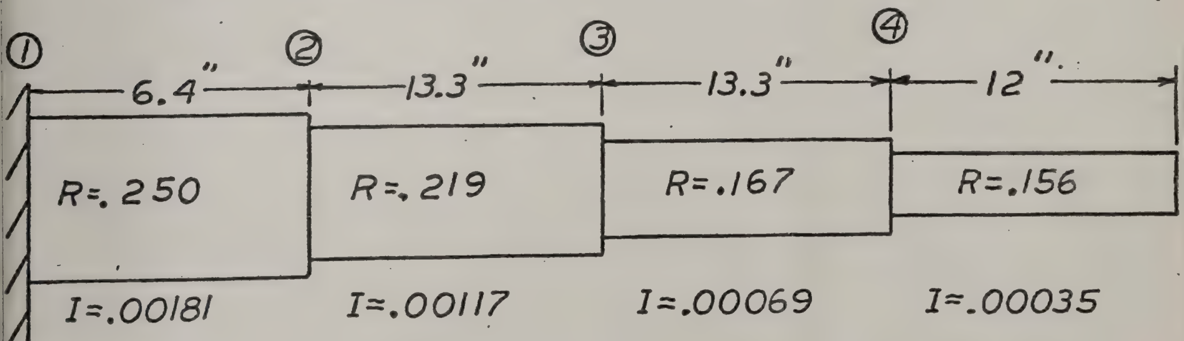


Figure F - Geometry of Cane 6

At Joint 1: $P_{max} = \dfrac{3.9 \times 10^{4} \times 1.51 \times 10^{-3}}{45 \times .25} = 6.3 \text{ lbs.}$

At Joint 2: $P_{max} = \dfrac{3.9 \times 10^{4} \times 1.17 \times 10^{-3}}{37.6 \times .219} = 5.4 \text{ lbs.}$

At Joint 3: $P_{max} = \dfrac{3.9 \times 10^{4} \times 6.9 \times 10^{-4}}{25.3 \times .167} = 6.4 \text{ lbs.}$

At Joint 4: $P_{max} = \dfrac{3.9 \times 10^{4} \times 3.5 \times 10^{-4}}{12 \times .156} = 7.3 \text{ lbs.}$

Therefore, the maximum load before deformation would be 5.4 pounds.

Appendix G - Simulated Tapping Machine

The apparatus to simulate a tapping motion is sketched in Figure G1. The canes were clamped in the device such that the tip extended 35 inches beyond the pivot point. The sound level meter was then placed approximately one foot away from the tip. The location was marked so that it would be the same for all canes. Figure G2 gives the dimensions of the machine employed.

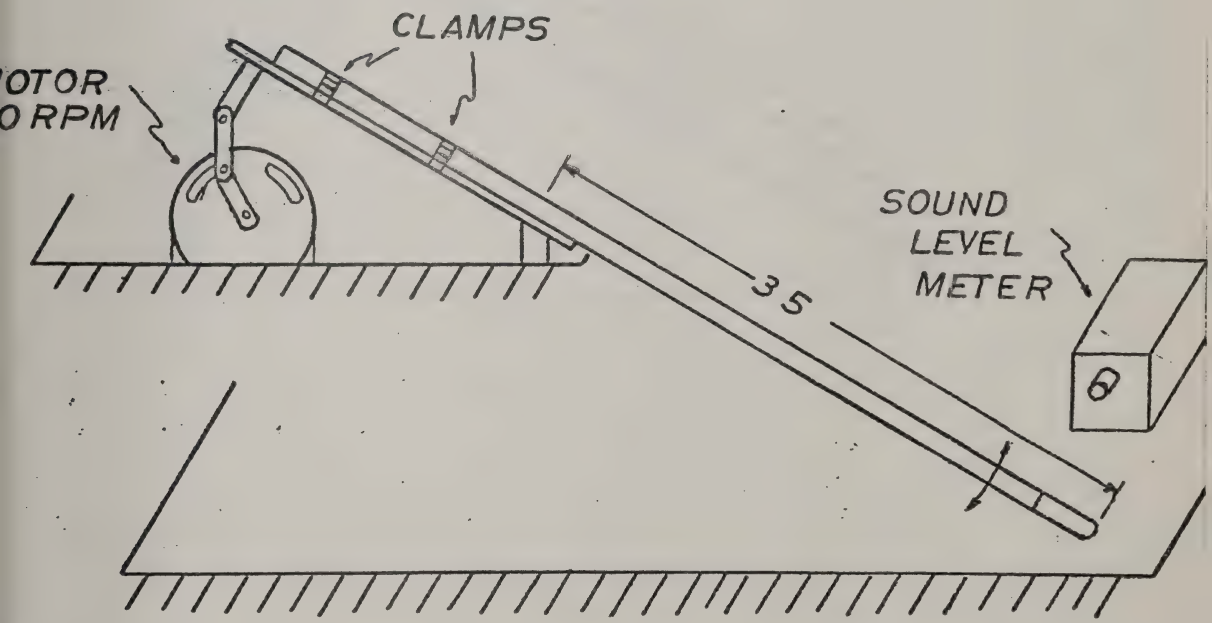


Figure G1 - Simulated tapping apparatus.

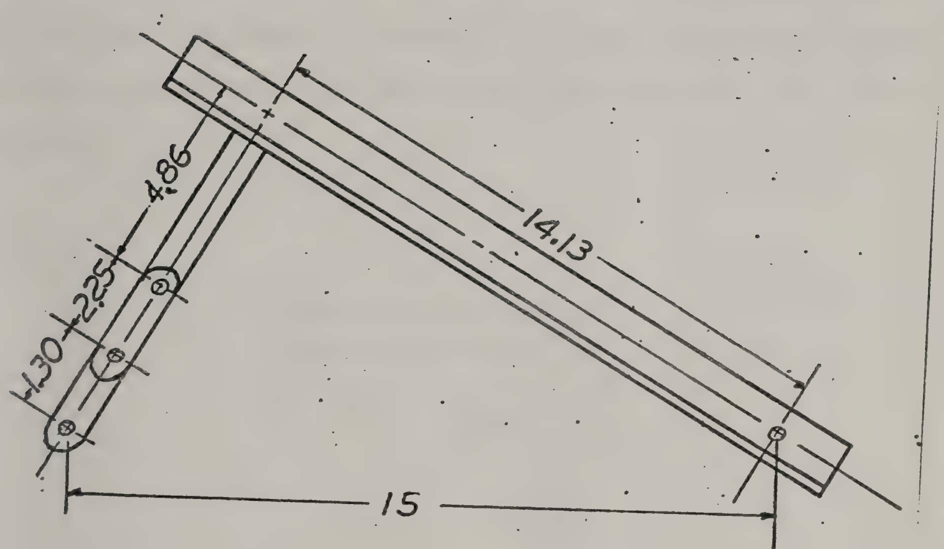


Figure G2 - Machine Dimensions

Appendix H - Axial Force-Strain for Elastic Cords

In order to find the force-deflection curves for the elastic cords, the following procedure was employed. The elastic cord was suspended from a rigid support, with a light dish (.35 lbs.) suspended from the other end. The length of the elastic cord was made to be 12 inches. Two marks six inches apart were placed on the cord. By adding weights to the pan and noting the new spacing between the marks the axial force-strain curve is constructed.

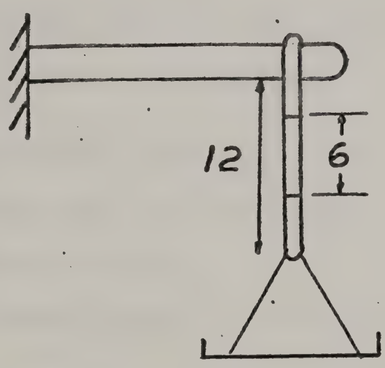


Figure H - Apparatus for Force-Strain of Elastic Cords

Appendix I - Replacing Components

This appendix gives a description of the disassembly of each cane. Unless otherwise specified, assembly is the reverse procedure.

Cane 1

To remove the tip:

1. On this cane the tip is riveted to the last section. This rivet must be drilled out.
2. The eyelet which holds the inner elastic to the tip is unscrewed.
3. When replacing the tip, the elastic cord will hold it in place, so there is no need to try to rerivet it.

To remove handle and wrist elastic:

1. Slit handle along its length and remove.
2. Remove wrist elastic.
3. Heat new handle before placing on cane.

To remove tubing sections:

1. Remove handle.
2. Untie inner elastic.
3. Replace defective section.

To replace inner elastic:

1. Remove handle.
2. Untie inner elastic.
3. Remove tip.
4. Replace elastic.

Cane 2

Tip replacement:

1. With cable in the fully released position pull tip from the last section.
2. Unscrew the eyelet holding the cable.
3. Replace tip.
4. Adjust the cable tension if necessary.

Cable tension adjustment:

1. Loosen set screw in handle (see Figure I1) with cane in collapsed position.

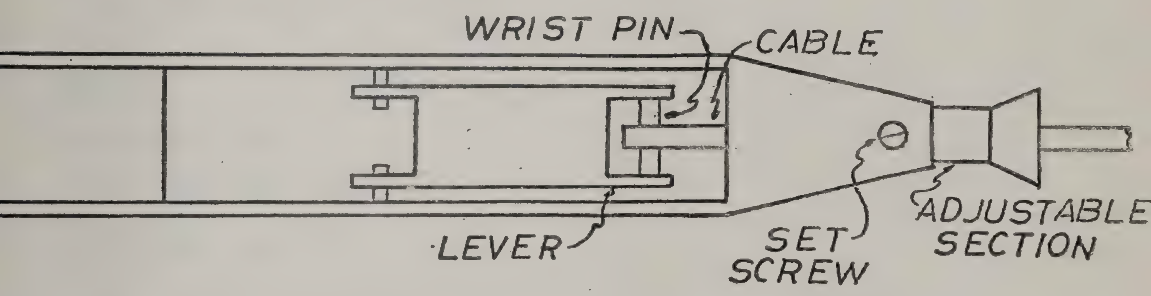


Figure I1 - Cable Tension Adjustment on Cane 2

2. Pull the adjustable section out if more tension is required, in if less tension is required.
3. Tighten the set screw.

To remove handle:

1. Knock out the wrist pin that holds cable in the handle.
2. Remove cable from handle.
3. Replace the handle.
4. Adjust cable tension if necessary.

To replace tubing sections:

1. Remove handle.
2. Replace defective section.
3. Attach handle.
4. Adjust cable tension if necessary.

To replace cable:

1. Remove handle.
2. Remove tip.
3. Replace cable.
4. Adjust cable tension.

Cane 3

To replace tip:

1. Tip pulls off.

To replace handle:

1. Same as Cane 1.

To replace elastic:

1. Remove handle and tip.
2. Pull on nylon attaching rope and untie (see Figure I2)

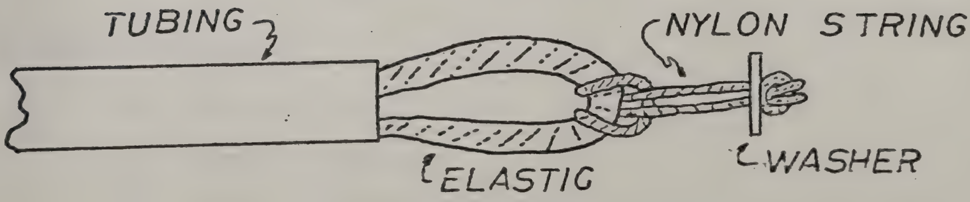


Figure I2 - Elastic Removal for Cane 3

3. When rethreading the elastic through the tubing, it may be useful to thread a string first and then wrap around the elastic and pull.

To replace tubing:

1. Remove tip.
2. Untie elastic at this end only.
3. Replace defective section.
4. Thread elastic.

Cane 4

To replace tip:

1. Unscrew.

We consider the rest of the cane not serviceable.

Cane 5

To replace the tip:

1. Pull it from the end of the cane and untie it.

To replace the tubing:

1. Remove tip.
2. Replace defective section.
3. Thread elastic cord (see Cane 3).

To replace handle:

1. Same as Cane 1.

To replace elastic:

1. Remove tip.
2. Remove handle.
3. Remove elastic from handle end (it pulls out).
4. Thread elastic (see Cane 3).

Cane 6

To replace tip:

1. Loosen set screw.
2. Replace tip.

To replace sections:

1. Remove tip.
2. Replace defective section.

To replace handle:

1. Same as Cane 1.

To replace elastic:

1. Remove tip.
2. Remove handle.
3. Replace elastic.

Canes 7 and 8

To replace tip:

1. The tip unscrews from the bottom section.

To remove tubing or locking mechanism:

1. Unscrew the knurled nuts.
2. Replace defective component.
3. When assembling make sure locking mechanism is as shown on Figure I3 and that the brass half nuts are aligned with each other.

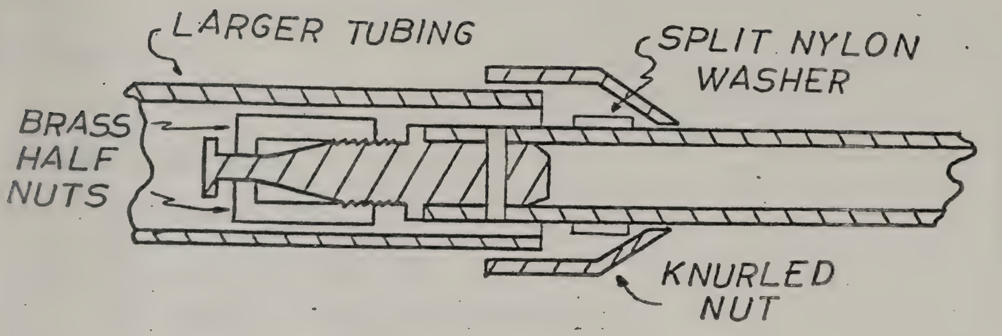


Figure I3 - Locking Mechanism for Canes 7 and 8

To remove handle (Cane 8 only)

1. Same as Cane 1.

<u>Cane 9</u>

To remove tip:

1. Unscrew the tip.

To remove the handle:

1. Same as Cane 1.

To remove the rope:

1. Remove tip.
2. Remove and untie the rope.
3. Pull rope out.
4. When replacing the rope it is more convenient to thread the rope from the tip to the handle.

To remove the sections:

1. Remove rope.
2. Replace defective section.

Cane 10

To remove tip:

1. Pulls off.

To remove sections:

1. Remove tip.
2. Pull end cap off.
3. Replace defective section.

CLEVELAND STATE UNIVERSITY
CLEVELAND, OHIO 44115

COLLEGE OF ARTS AND SCIENCES
DEPARTMENT OF SOCIAL SERVICES

(216) 687-4560

February 3, 1978

Mr. Alex H. Townsend
Director
Sensory Aids Development
The American Foundation for the Blind, Inc.
15 West 16 Street
New York, New York 10011

Dear Mr. Townsend:

Thank you for asking me to comment on the Cooper Union Report, regarding the performance of nonrigid canes. I am excited in providing input to this project, because I have been involved in the selection of the Orientation and Mobility Specialists, that have been evaluating the use of canes. As past president of the National Orientation and Mobility Interest Group, of AAWB, I helped organize the evaluation progress by the interest group. My input, now, regarding the Cooper Union Report, will help me tie these two areas together.

I would like to begin by saying that the Cooper Union Report is a substantial addition to the knowledge, regarding nonrigid canes. The report has many helpful pieces of information, and the Sensory Development Division of AFB should be commended for undertaking this project. There has been much of a mystique regarding collapsable canes, which this report sheds light upon. In general, I feel information regarding the performance of these canes will be most helpful to the consumer and to Mobility Specialist's recommending aids.

The beginning section of the report has diagrams of the construction of the variouscanes. I feel it would also be helpful to have actual photographs of the canes in their rigid and nonrigid condition, allowing the individual to visualize these products as they are mentioned in the report.

On page four, table one, there is a summary of cane ratings, which I feel, has one very important element missing, the conductivity of the cane. In other words, how easily can the individual distinguish one surface material from another, through the cane. This is often an important element when traveling through an area, and trying to determine whether one is approaching cement, asphalt, dirt, gravel, etc. The tradition in one piece canes has been to build canes which conduct vibrations easily from the tip of the cane through the shaft to the users hand, allowing for this differentiation to be made. The materials of that cane have been selected primarily to allow excellent conductivity. In the past, criticism of nonrigid canes, has been that the various sections tend to break the transmission of vibrations from the tip to the users hand. Therefore, I feel, an evaluation of this component would be most helpful.

February ,

[illegible]

Dear Mr. Townsend:

[illegible]

On page five, there is a list of the highly recommended, and not recommended canes. I am wondering if this section may appear a bit too early, and should be held towards the end of the work, summarizing the effort. Furthermore, I am very concerned about how the priorities were established, allowing one cane to be recommended above the other. Were these the priorities of the engineers testing the canes, or the priorities of blind individuals field testing canes, along with Mobility Specialists evaluating their use? I feel a combination of these factors would be more appropriate than just the evaluation of mechanical aspects of the cane, independently. Furthermore, prior to recommending canes, I feel, it is necessary to discuss the criteria for the recommendations rank ordering the most important elements to the least important with the rationale for this choice.

On page eight, in the first paragraph, it is mentioned that the features of the cane include length. I feel that it should be pointed out that the length varies from cane to cane, and this affects other variables, such as weight. In the second paragraph on this page, it is mentioned that when a cane is fairly supported (free tip) that the use must resist the weight of a cane. I think an explanation of what free tip means may be helpful. Further down in the paragraph, it states that the lower the tip rotation ratio, the less effort required by the user when the cane is fairly supported. I feel a practical example of this would be helpful here. On page nine, paragraph one, the tip weight ratio is discussed. Ordinarily, the cane is not supporting weight through the tip unless a procedure, such as the touch and slide technique is implemented. That procedure allows the user to touch the cane tip on one side of the arc, and slide it to gain further information regarding the texture on the ground by noting the resistance of the cane tip as it glides over a particular surface. Therefore, the tip weight ratio would be most important for the individual using the touch and slide technique while traveling. This technique is used on and off by many travelers, depending on the need for information about the surface they are about to step on. In addition, more travelers are beginning to use that technique as a replacement for the more standard touch technique.

In the first paragraph on page 10, you mentioned that since the purpose of buying a cane of this kind is to fold it so that it can be hidden, or conveniently held, it is considered that the smallest over all dimenisons accommodate compactness. I feel that the choice of the word hidden is poor. It denotes that the cane is stigmatizing. I feel a better choice would be to indicate that the cane can be conveniently folded and put out of the way when not in use.

On page 10, under Four Discussion, A. Cane Weight, I think that it needs to be discussed that the weight of a cane depends on the length. Therefore, the table two on page 11, comparing different canes and the weight, should take into consideration the length. The last paragraph on page 12 indicates that you conclude the appropriate collapse length should be between nine to fifteen inches. How is that appropriate length determined? Is it the modal length?

Page 13, the last paragraph, I found somewhat confusing. I think it needs further elaboration. Then on page 15, the last paragraph, axial compressive, again I think needs more direct explanation. On page 16, under figure two, you explain that this picture is a representative of cane tip running into an obstruction and the user push causing the compressing load. I feel this is a good example helping the reader undersand what is being tested. More such examples like this of a practical nature would be helpful throughout the report. On page 17, in the first paragraph, it stated more information obtained by the user. I believe this to be true, but has that been established scientifically? Further down in the paragraph, it is stated, in normal use the cane is generally tapped on the ground. I feel that in addition to that we should state the cane can be slid for a short period of time.

On page 28, mention is made that the fiber glass cane is too flexible too transmit useful information to the user. In another section of this report, it is mentioned that the cane buckles easily, and does not provide rigidity to allow an individual to stop prior to bumping into an object. These disadvantages seem major and I am wondering why this cane is recommended so highly?

On page 32, I feel that a better explanation of tensile force would be most helpful.

On page 34, the second paragraph, it is mentioned that if the metal should wear the joints will go in further to lock, but they will lock just as if they were new. Is there not another variable here affecting this locking? It would seem to me that the ability of the cord to maintain its tensile strength may be another factor.

On page 49, the first paragraph, reads, "we conclude here, that a well designed cane should require a force of less than 10 pounds. (Five pounds preferred) Also, a time of no more than three seconds to open it." Where does this conclusion come from? Is it an average? Is it a priority? Is it the lowest available time? This should be established.

On page 52, the second paragraph, talks about the important function of a cane tip creating sound as it is tapped by the individual. Many blind travelers may take issue with the importance of this function since many prefer a quiet cane and get their auditory information from ambient sound in the environment, rather than creating their own. They feel that tapping and making a loud sound may make them conspicuous. The paragraph following this, states that a spectral analysis would produce little useful information. If mentioned of sound continues to be part of this report, a spectral analysis might be helpful, since research has shown that blind individuals rely on frequencies of 10,000 hz. for echo detection abilities.

On page 53, the bottom of the first paragraph, it is said that since most users simply use off the ground tapping motion, the friction involved in walking with a cane cannot be considered as a primary design criteria. Many Mobility Specialists and blind clients may take issue with that. Those who use the touch and slide technique use the friction to get information regarding characteristics of ground texture. This is especially true as individuals approach a perpendicular street. They will often slide the cane tip on the ground in order to tell the difference in texture between the cement the cane is on, and the asphalt they are approaching. I feel this is an important factor that should be evaluated.

[illegible] last paragraph, I found it somewhat confusing. I [illegible] [illegible]. Then [illegible] the first paragraph, vital generation, [illegible] more direct application, [illegible] that this might be a more [illegible] into an [illegible] and [illegible] the perception [illegible]. I [illegible] the [illegible] and its [illegible]. [illegible] of a [illegible] would be helpful to [illegible] the report. [illegible] the first [illegible], it [illegible] information [illegible]. [illegible] this to be true, but [illegible] used in the [illegible]. It is [illegible]. I feel that in addition to this, we should [illegible] for a [illegible] period of time.

On page [illegible], mention is made that the [illegible] is [illegible] useful information to the user. [illegible] mentioned that the same belief; mostly, [illegible] individual [illegible] prior to [illegible]. [illegible] a question why this [illegible] is necessary?

On page [illegible], I feel that a [illegible] explanation of [illegible] would [illegible].

On page [illegible], the second paragraph, it is mentioned [illegible] points will be further to [illegible], but [illegible] it would be a variable [illegible]. [illegible] that [illegible] of the [illegible].

[illegible] the first paragraph, [illegible] would have [illegible] well [illegible] would need a [illegible]. [illegible] a time of [illegible]. Where does this [illegible]? Is it [illegible]? Is it the [illegible] available [illegible]?

On page [illegible], the second paragraph, [illegible] about the important function of [illegible] sound as it is [illegible] by the individual. [illegible] with the importance of [illegible] their auditory information [illegible] in the environment, rather than [illegible]. They [illegible] information. If [illegible] continues to [illegible] approach has shown that [illegible] individuals rely on [illegible], for echo detection [illegible].

[illegible] the bottom of the first paragraph, it is [illegible] that [illegible] sound [illegible] the [illegible] involved in walking [illegible] considered as a [illegible]. [illegible] blind [illegible]. This is [illegible] to individuals [illegible] approach a [illegible]. I [illegible] evaluation.

On page 56, table 11, the loudness levels in decibels, should be labeled SPL, or an indication of the setting of a sound level meter would be helpful, whether it was weighted or unweighted. Page 57, tip area, presents an issue which is not often discussed. Mobility Specialists have not given much emphasis to the area of the tip, and if anything have preferred somewhat narrow tips. It may very well be, however, that the wider tip area will prevent the cane from sticking, as long as the sensitivity of the cane tip was not impaired. Furthermore, the sensitivity of a cane tip, or its conductivity of vibrations, should be measured as another important variable.

On page 59, is is mentioned that a moderately long handle provides an easy and quick way of adjusting the length of the cane. I feel that is should be mentioned that canes are prescribed for the stride and heights of the individual and should not be longer than necessary, but it may be helpful to have a handle cane in congested area travel.

On page 66, the first paragraph, I feel some mention should be made regarding deterioration in tensil strength of the cord after use, or in varying temperature conditions.

On page 90, the durability of the canes was summarized. It appears that canes 5, 7, 8, 9, and 10 deteriorated the least. This may be one of the criteria which should be extremely important in recommending canes since most Mobility Specialists are reluctant to recommend folding canes for outdoor travel, due to the fact that they can fall apart in a travel situation, causing much problem for the user.

Once again, I must state that the establishment of recommendations for the canes should be as objective as possible. Some of the characteristics of canes, not highly recommended, may be more important to the blind user than the Cooper Union believes. Therefore, this publication should take into consideration those elements that are most important.

I have a major concern which I feel this report must address. At the present time, there is much controversy within the ranks of Orientation and Mobility Specialists regarding whether or not the collapsable cane is an affective enough tool to allow its use in outdoor travel situations. The majority of Mobility Specialists do not recommend that folding canes be used in outdoor travel situations. They contend that since the sensitivity of the cane is not as good as the one piece cane that the folding cane should be restricted to indoor travel only. They further base this conclusion on the lack of durability, often resulting in a broken cane in an outdoor travel situation. This report seems to imply that certain folding canes can be recommended for outdoor travel. I have come to this conclusion in part after reading on page 98, the material in parenthesis under cane 10. This reads, "This cane is ideal for light indoor use with no adverse external conditions." What is implied here is that this particular cane should be restricted to indoor use. Other canes carry no such warning, and therefore, one may gather that they are being recommended for outdoor travel. I feel this issue should be mentioned in the report, and if

In case [illegible], cane 11, the lightness [illegible]. [illegible] the addition of the section of a rigid [illegible] [illegible] considered an advantage. Cane [illegible] [illegible]. Mobility Specialists [illegible] [illegible] and [illegible] have employed [illegible]. [illegible] however, that the wider tip area will [illegible] the cane tip is not involved. Furthermore [illegible] the sensitivity of the cane tip [illegible] of a cane tip, or its conductivity of vibrations, should [illegible] important variable.

In case [illegible], it is [illegible] that a [illegible] which way of adjusting the length of the cane. I feel that [illegible] that canes are prescribed for the [illegible] and [illegible] of the individual [illegible] a [illegible] longer than necessary, [illegible] a [illegible] [illegible] connected upon travel.

In case 6, the first [illegible], I feel cane [illegible] would [illegible] [illegible] to the [illegible] of the [illegible] [illegible] [illegible] conditions.

[illegible] case [illegible], the [illegible] of the cane [illegible] [illegible]. [illegible] [illegible] 7, 6, and 1 [illegible] the least. [illegible] [illegible] should be extremely important in [illegible] canes [illegible] [illegible] [illegible] Specialists are reluctant to recommend [illegible] [illegible] [illegible] that they can fall apart in a travel [illegible] [illegible] for the [illegible].

[illegible], I [illegible] that the [illegible] of [illegible] should be as [illegible] as possible. [illegible] of the [illegible] of canes [illegible] highly recommended may be [illegible] in [illegible] [illegible] deliver. [illegible] this [illegible] should [illegible] [illegible] [illegible] that [illegible] important.

I have [illegible] I feel is [illegible]. [illegible] there is much controversy within the [illegible] of [illegible] and Mobility Specialists [illegible] whether or not the collapsible cane [illegible] [illegible] to allow its use in outdoor travel situations. The majority of [illegible] Specialists do not recommend that [illegible] canes be used in outdoor [illegible] situations. They contend that since the sensitivity of the cane [illegible] as the [illegible] cane that the folding cane should [illegible] travel only. They further base this conclusion on the [illegible] resulting in a broken cane in an outdoor travel situation. This [illegible] [illegible] that certain folding canes can be recommended for outdoor travel. [illegible] to this conclusion in [illegible] reading on case [illegible], the [illegible] [illegible] cane 11. This cane [illegible] is ideal for [illegible] use with no adverse external conditions. [illegible] is [illegible] is [illegible] particular cane should be [illegible] to indoor use. [illegible] canes [illegible] [illegible], and therefore, one [illegible] that they are [illegible] for outdoor travel. I feel this [illegible] [illegible] [illegible] in the [illegible]

outdoor use is not intended as the recommendation it should be indicated that no decision on this has been made. I feel another section to this report might be necessary, which would compare the folding cane to the one piece cane in its sensitivity. Such an evaluation of this should be done objectively with scientific measurements, and should also be judged subjectively by Orientation and Mobility Specialists, and by blind travelers.

I wish to thank you for giving me the opportunity of communicating my thoughts regarding the Cooper Union Study. I hope by observations will be helpful to you. If you have any further questions, please do not hesitate to call or write.

Sincerely yours,

Bill Wiener

Bill Wiener
Associate Professor
Orientation and Mobility Sequence
Cleveland State University

bc